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Global Food Demand Patterns Over Changing Levels of Economic Development

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GLOBAL FOOD DEMAND PATTERNS OVER CHANGING LEVELS OF ECONOMIC DEVELOPMENT.
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ABSTRACT

Global food demand is analyzed for three U.S. export commodity groups: coarse grains, wheat and rice, and meat. The analysis provides insight into potential export markets by anticipating changes in countries' food demand as economic development proceeds. Global demand functions for the food groups were estimated by pooling cross-sectional and time series data for 105 countries. These functions were graphed to show the changing commodity composition of global food demand and associated income ranges.

Keywords: global food demand, economic development, consumption patterns, income.

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SUMMARY

The analysis supports the following statements about global food demand/consumption:

1. Six distinct stages of economic development are characterized by changing consumption patterns. The low-income developing countries are represented in stages I and II. In stage I, consumers substitute wheat and rice in the diet for coarse grains, while meat and wheat and rice consumption complement each other. In stage II, the share of wheat and rice consumption surpasses coarse grain consumption, while meat consumption begins to rise rapidly.

2. Stages III and IV describe the middle-income ranges. Stage III is characterized by stabilizing percentages of wheat and rice in the diet, and shares of meat in the diet are greater than shares of coarse grains. Stage IV shows meat consumption as a percentage of the diet substituting for wheat and rice and coarse grains. Wheat and rice consumption as a percentage of the diet peaks and then begins to decrease in the middle-income ranges.

3. High-income countries fall into stages V and VI. In stage V, meat consumption accounts for the largest share in the diet, greater than wheat and rice and coarse grains. Stage VI shows the percentage of meat in the diet declining along with the other two groups. The share of meat reaches a maximum and then begins to decline in the high-income ranges.

4. When global consumption of coarse grains and wheat and rice are in equal proportions in the diet, the average consumer is at the point of nutritional caloric adequacy.

5. Income elasticity of demand patterns for wheat and rice and meat show a range of increasing elasticities at the extreme low income level, thus challenging Engel's Law.

6. Consumption patterns for the meat subgroups at the highest observed income ranges reveal that demand is increasing for both pork and poultry meats, but is decreasing for beef and sheep and goat meats.

7. High feed requirements for pork and poultry production imply increasing derived demand for feedgrains as incomes increase.

8. Middle- and upper-income range developing countries represent the greatest potential for U.S. exports of food- and feedgrains because of purchasing power and rising derived demand for feedgrains.

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INTRODUCTION

This study analyzes global food demand for three groups of agricultural commodities that influence U.S. exports: coarse grains, wheat and rice, and meat. Demand for these commodity groups is examined over changing levels of economic development. The analysis thus focuses on changing global food demand for these three food groups as levels of economic development change. We hypothesize that on a global scale, the mix of food commodities demanded will change in a predictable manner as economic development proceeds.

The basic concepts of economic development and food demand were operationalized by constructing proxy measures. These measures were per capita gross domestic product and per capita availabilities for human consumption of coarse grains, wheat and rice, and meat. Statistical estimates were made by pooling cross sectional data for 105 countries and time series data for 1961-81 to test the general hypothesis that consumption varies predictably with economic growth. The estimated demand functions for the three commodity groups were graphed simultaneously to show the changing composition of global food demand and to determine income ranges in which a specific commodity mix can be anticipated. Changing food demand patterns have implications for both global and U.S. trade.

COMMODITIES DEMAND AND GLOBAL TRADE

Declining quantities and values of U.S. agricultural exports, along with rising U.S. production, have signaled an urgent need to develop new export markets. Identification of potential new markets requires an analysis of worldwide demand for commodities that the United States exports. Economists generally affirm that the level of economic development strongly influences the quantity and quality of food demanded in the human diet. Food demand patterns for specific commodities are widely believed to change as a nation's level of economic development changes. Hence, there is a need to anticipate the direction and the magnitude of these changes as one step in the overall effort to identify new export markets.

Food demand has many determinants in addition to economic development. Among these are relative market prices of both food and nonfood items. For example, the strong U.S. dollar compared with other currencies in the early 1980's is one factor that has diminished American competitiveness on the international market for agricultural commodities. Foreign exchange earnings and commitments along with various trade and taxation policies also influence food demand in a specific country. Demand has been constrained in the developing nations by declining export revenues and by increasing debt service obligations. A well-specified estimation model of food demand across countries would include these variables.

Attempts to investigate global food demand raise problems of time series data availability and validity across enough countries to warrant the term "global." Maintenance of a global focus requires a compromise on model specification. Of the variables mentioned above, only income data is available

over enough years for sufficient countries to permit global analysis. These data difficulties and the pervasive premise in economic literature that income, as a measure of economic development, is the major determinant of food demand provide the rationale for this study.

Since the United States is the major exporter of wheat and the second most important rice exporter in the world, the study of wheat and rice demand is crucial to the future of U.S. trade. Although meat is not a major U.S. export, understanding the demand for meat provides insight into future demand for feed grains. Since the United States leads the world in exports of grains typically used for feeding livestock, more information is needed on those countries which are likely to increase their demand for meat and to intensify their livestock production, thus increasing their demand for feed grains.

Some suggest that the recent failure of U.S. agricultural exports is not abnormal and that exports will continue to decline in the future. While this remains questionable, it is important to investigate whether potential exists for growth of U.S. exports, to determine where that potential lies, and to identify the commodities.

UNDERLYING THEORY

Economic development leads to increased employment and higher resource productivity, thus increasing disposable income for individuals and households. Additional disposable income early in the development process directly increases the demand for food, particularly for preferred food grains and animal products. A USDA study associating food demand with income changes in developing countries states that: "The transition of an economy from a stagnant state, where population and income remain constant, to an economy with high levels of per capita income is likely to increase the rate of growth in food requirements at the farm gate by as much as 5 percent per year in the early stages of economic development before it finally decreases to about 3 percent"(20).[1] Measuring demand changes for different food commodity groups as economic development proceeds provides valuable information about the potential for global agricultural commodity exports, especially to developing nations.

The Variables

The measurement of food demand across many countries, covering a broad spectrum of economic development levels, constrains the analysis to the use of proxy measures for the true variables. Within economic literature, income (or total expenditures) is most frequently used as the proxy measure for economic development. Food demand is often approximated by food available for human consumption based on total supply-utilization data for a country. While household surveys provide a more accurate measure of income distribution and of consumption variations among populations within a particular country, these surveys do not exist for many countries and the data often are not comparable worldwide. Thus, this and other global studies are forced to use annual national data to correlate income with food consumption across many countries.

Consumer Demand Theory

Traditional Marshallian theory, as cited in Deaton and Meullbauer (2), relates a household's demand for a particular commodity to prices and income by:

$$(1) \qquad q_i = g_i(x, p)$$

$$\text{where } q_i = \text{quantity demanded of commodity i}$$

$$x = \text{income}$$

$$p = \text{price}$$

---

[1] Underscored numbers in parentheses refer to sources listed in the References section.

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This equation provides the basis for the solution to the household's problem of choosing commodities to maximize utility subject to a budget constraint (income x):

(2) $$\text{Maximize } u = v(q), \text{ subject to } p*q = x$$

where u = utility.

Economists usually assume that consumers face linear budget constraints. That is, the choice of quantities to consume is constrained by fixed, known prices so that the total value of commodities consumed does not exceed the budget or income available. The satisfaction of the budget constraint places two restrictions on the demand function, g_i. The first constraint, the adding-up or additivity restriction, requires that changes in income (x) and prices (p) cause the consumer to change the commodity mix so that the available budget is not exceeded. This implies:

(3) $$\sum_n p_i * \left(\frac{\partial g_i}{\partial x} \right) = 1 ; \sum_n p_i * \left(\frac{\partial g_i}{\partial p_i} \right) + q_i = 0 \text{ for } i = 1, 2, 3, \ldots n$$

where n = all commodities,

i = an individual commodity, and

g_i = the demand function as in equation 1, and

$\frac{\partial g_i}{\partial x}$ = the first derivative of equation (1) with respect to income.

The second restriction, homogeneity, requires that purchases of good i remain unchanged for proportionate changes in prices (p) and income (x). This is satisfied if:

(4) $$\sum_n p_i * \left(\frac{\partial g_i}{\partial p_i} \right) + x * \left(\frac{\partial g_i}{\partial x} \right) = 0 \quad \text{for } i = 1, 2, 3, \ldots n$$

A complete set of demand functions must meet two more properties in addition to additivity and homogeneity: symmetry and negativity. These properties guarantee that consumers have consistent preferences and follow rational choices. For symmetry and negativity, the compensated price responses (cross-price derivatives of Hicksian demand functions) must be symmetric and they must form a negative semidefinite matrix [2].

Engel Curves

Several cross-sectional studies of consumer behavior have sought to explain changes in quantity demanded simply by the variation in income, without prices [1, 5, 22]. The lack of reliable price data across countries is one reason for this omission. Also, Deaton and Meullbauer state that demand derived as a function of prices "only makes sense if prices are set exogenously (say by manufacturers) and quantities supplied elastically to meet whatever demand emerges. This is probably the case for most goods in modern industrial societies, although food may be a partial exception and it is interesting to note that food is a commodity for which many authors have had difficulty in estimating a 'sensible' price elasticity" [2]. In many developing countries, and for certain commodities within industrial nations, prices are administered, not set by the free market. In addition, over the extended time period needed for economic development, income (not prices) may well be the principal determinant of changes in food consumption patterns.

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For the above reasons, prices are often left out of the demand model and consumers are assumed to face constant relative prices. Consequently, the homogeneity restriction is not applicable to the demand function since there is no price variation. Likewise, the symmetry and negativity properties cannot be tested. However, the additivity constraint remains to be satisfied. But this constraint can be imposed only if demand equations are estimated for all commodities within the set of consumption possibilities. Hence, for studies that focus on the relationship specifying quantity demanded for an incomplete set of commodity groups solely as a function of income, Engel curves are an appropriate analytical approach. The Engel curve is defined as:

(5) $$q_h = g_h(x)$$

where h = a commodity group made up of

individual food commodities

Utility Maximization

The concept of separability allowed Christian Lorenz Ernst Engel to analyze the relationship between income and food consumption. He developed the Engel curve on the assumption that food consumption is independent of consumption of other goods within the household's budget, such as housing or entertainment. Given separability, commodities are partitioned into the two groups, food and nonfood, so that preferences among commodities within the food group can be described independently of consumption in the nonfood group. Separability of preferences implies that subutility functions exist for each group and that the subutilities combine into one equation to equal total utility:

(6) $$u = f\left[v_f(q_1), v_{nf}(q_2) \right]$$

where u = total utility

v_f = utility derived from food commodities q_1,

v_{nf} = utility derived from nonfood commodities q_2.

The food subutility function is maximized subject to a food budget constraint. This utility maximization process enabled Engel to derive a demand function for the food commodity group.

By analogy, the food group may be further divided into subgroups, with unique underlying utility and demand functions. For purposes of discussion, three food subgroups are assumed to exist: a least preferred, a preferred, and a most preferred food group. The following utility tree helps represent the relationships:

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All commodities

Food   Nonfood

Least preferred   Preferred   Most preferred
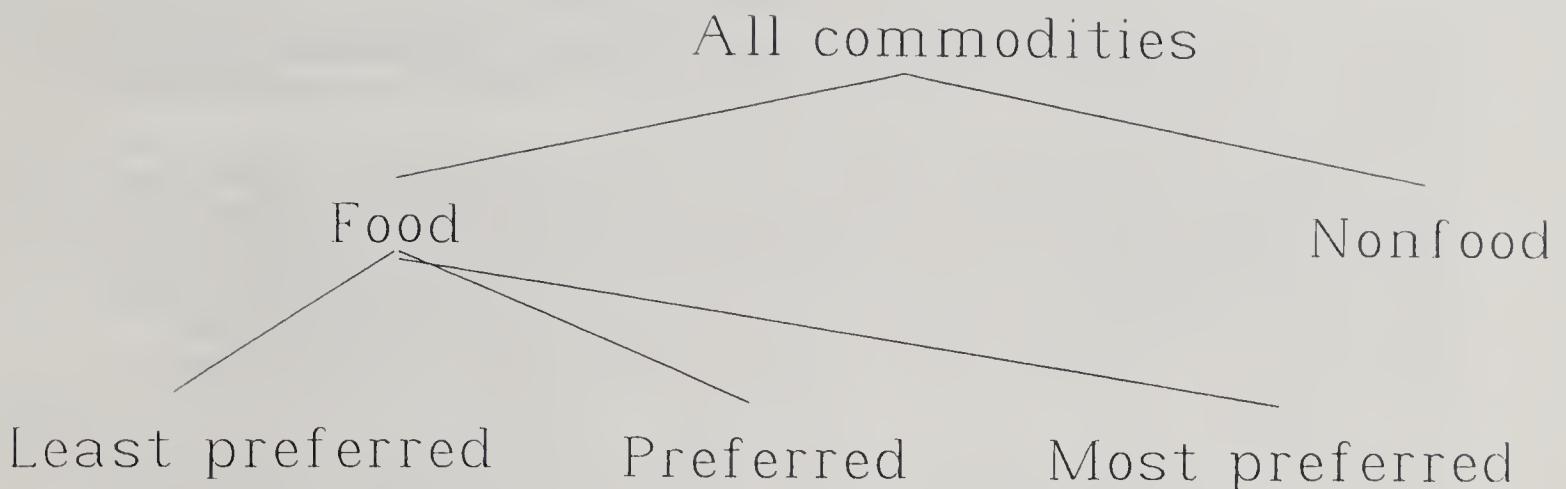
Just as separable preferences imply subgroup demand functions, the converse is also true (2). Thus, the existence of separate demand functions would imply separability of preferences. For example, DeJanvry verified that the meat category forms a separable subgroup within the food group (3).

Weak separability is described by a utility function of the form:

(7) $$u = f\left[v_L(q_1, q_2), v_P(q_3, q_4), v_M(q_5, q_6)\right]$$

where v_L = utility derived from commodities 1 and 2 of least

preferred group L

v_P = utility derived from commodities 3 and 4 of preferred

group P

v_M = utility derived from commodities 5 and 6 of most

preferred group M

while strong separability requires an additive utility function:

(8) $$u = f\left[v_L(q_1, q_2) + v_P(q_3, q_4) + v_M(q_5, q_6)\right]$$

The restrictions on behavior under strong separability rule out economically inferior and complementary commodities. Weak separability allows whole groups to be either substitutes or complements for each other; however, the degree and manner of substitutability or complementarity between commodities in different groups is limited. For example, assuming constant prices, income-induced substitution of commodity 3, group P, for commodity 1, group L, must occur in the same manner as the substitution of commodity 4, group P, for commodity 2, group L.

The preceding utility tree suggests that two-stage budgeting takes place. First, the consumer allocates income to the broad commodity groups and second, to the food subgroups. In the first stage, the consumer chooses the quantities of food and nonfood commodities that maximize his total utility function within the available budget. In the second stage, choices are made among commodities in the least preferred, preferred, and most preferred groups to maximize the food subutility function subject to a food budget constraint.

The Aggregation Problem

Demand theory and utility maximization derive from the individual consumer or household as the unit of analysis. Applying individual consumer demand theory to the use of national aggregate data creates difficulties, commonly referred to as the "aggregation problem."

This aggregation can be made without error only under two very strict assumptions: 1) that income distribution remains constant, and 2) that demographic composition (age, sex, education, number of children, etc.) remains constant (2). If income distribution varies, then exact linear aggregation theory requires the Engel curves to be linear. Consistent nonlinear aggregation requires that Engel curves vary linearly with one another as income changes under constant prices. However, Houthakker and Taylor state that "of all the errors likely to be made in demand analysis, the aggregation error is the least troublesome" (6). Hence, even if the above two assumptions do not hold, the aggregation error is typically ignored.

Hicks argued that variations in circumstances of individual households average out to negligible proportions in the aggregate, leaving only the systematic effects of variations in prices and incomes (2). If Hicks' view holds, then consumer theory based on the individual can be directly applied to aggregate data with no modification, that is, the sum of individual consumer quantities demanded equals the national aggregate quantity demanded. Thus, average consumption patterns computed from aggregate data can be related to average income.

Engel Curves for Most Preferred, Preferred, and Least Preferred Foods

The choice of functional forms for demand equations must conform to both empirical evidence and to theory about consumer behavior. The classification of foods into three subgroups, most preferred (luxuries), preferred (necessities), or least preferred (inferior goods), would facilitate the choice of demand equations. Figure 1 below, used by Goreux, illustrates the shape of the demand function for these three categories of foods.

Figure 1 -- The Presumed Relationship of Income to Categories of Economic Goods

6
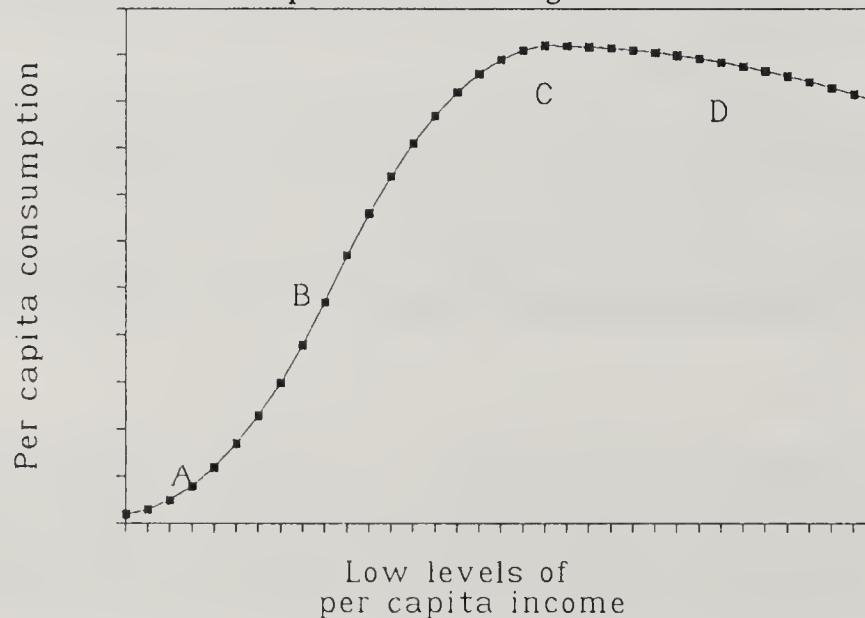
"The first segment AB of the curve represents the consumption of a luxury commodity which increases rapidly with income; segment BC represents the consumption of necessities, for which the rate of increase in consumption diminishes progressively as income rises; segment CD represents the consumption of an inferior good, which diminishes as income rises" (5).

It is important to realize that some foods may change in dietary importance from relative luxuries at lower incomes, to necessities as incomes rise, and to inferior goods at the highest income levels. These foods require a complex demand equation, similar to that in the above figure. For example, Goreux suggested in his 1960 article that across many countries, cereals might exhibit this changing nature over broad income levels, but he conceded that the data required to test the hypothesis over the entire curve were not available at that time (5).

An estimation of the Engel curve relationship between quantity demanded and income is useful in economic analysis. The percent change in quantity demanded due to a 1-percent change in income, referred to as the income elasticity of demand, is another useful tool that provides a unit-free measure of the influence of income on consumption. The income elasticity of demand is defined as:

$$(9) \qquad E_h = \frac{\dfrac{\partial g_h}{q}}{\dfrac{\partial x}{x}} = \left(\frac{\partial g_h}{\partial x} \right) * \left(\frac{x}{q} \right)$$

where $\dfrac{\partial g_h}{\partial x}$ = the first derivative of equation 5 with

respect to income

Much of the research literature computing income elasticities of demand assumes that elasticities remain constant over all income levels. However, the assumption of constant elasticity may not hold for either specific commodities or for total food. Engel observed that a household's percent of income spent on total food declined as income increased, thus permitting the possibility of a decreasing income elasticity of demand (Engel's Law). A review of studies finds that estimates of income elasticity of total food, a necessity with no real substitute, vary from 0.9 to 0.4 as income rises (20).

Elasticities for different foods may vary from negative values for least preferred (inferior) foods, positive values less than one for preferred foods (necessities), and positive values greater than one for the most preferred (luxury) foods. Foods of animal origin or high protein foods (such as meat, fish, and eggs) are generally thought to have higher elasticities than staple foods (such as cereals) that are generally starchy in composition (14). Consumers appear to consider meat a luxury, thus it often has elasticity values greater than one (11). Staples, on the other hand, generally have elasticity values between zero and one since they are necessities. However, elasticities may differ among staples. For example, because wheat and rice are preferred grains, they tend to have higher income elasticities than the coarse grains used for food (4).

Exception to Engel's Law

An exception to Engel's Law of declining elasticities of food as income increases may occur at the extreme lower income level. Thomas Poleman stated this reasoning as: "A final factor underlying the frequent failure of Engel's Law to strongly manifest itself in developing countries is that per capita food outlays, particularly at the lower end of the income spectrum, can be quite responsive to increases in income. . . . A number of surveys have suggested that the abjectly poor -- people near starvation -- will use an increase in income first to enlarge food intake and that the full Engelian relationship in fact looks something like (figure 2)."

Figure 2 -- An Exception to Engel's Law
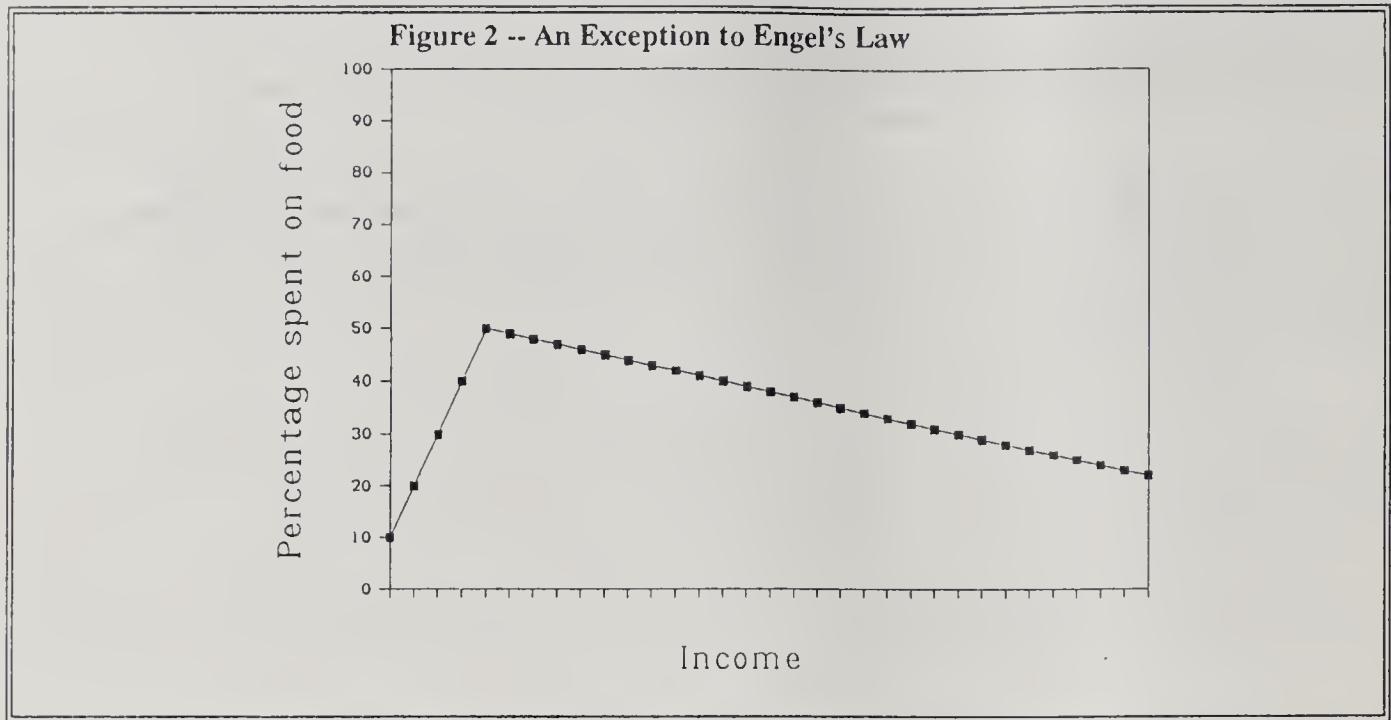
"The income level associated with the point of inflection is clearly an important threshold. Below it a family behaves as if it perceives itself to be inadequately nourished; beyond it as if food no longer posed the most pressing demand on income. Indeed, this point on the income range was the original definition of the poverty line" (15).

Many studies have provided support for Engel's Law for certain commodity groups (1, 11, 14). Yet, few have tried to investigate the exception to Engel's Law at the lowest income range on a global scale. An increasing elasticity of demand for food at the lowest income range would indicate a progressively greater percentage change in quantity of food demanded for a 1-percent increase in income. This requires the Engel curve to follow the form Goreux described for a luxury good (fig. 3).

If Poleman is correct in suggesting that the Engel curve for total food increases along the lower income portion, then the assumption of a diminishing marginal rate of substitution of food for nonfood commodities does not operate at that lower end of the income spectrum. Instead of acting as a necessity, food may act as a luxury item at low incomes. Thus, the marginal utility gained from an increase in income would rise to some maximum point before declining.

If the hypothesized changes in demand for the three food groups are empirically supported, then the income elasticities of demand may be nonlinear functions of income. As income changes, a food group may change from a most preferred item to a preferred item, and finally to a least preferred item. Thus, instead of remaining constant or declining as a linear function, these elasticities are expected to change in a nonlinear manner as income increases.

Figure 3 -- Expected Engel Curve for Luxury Goods

Per capita consumption
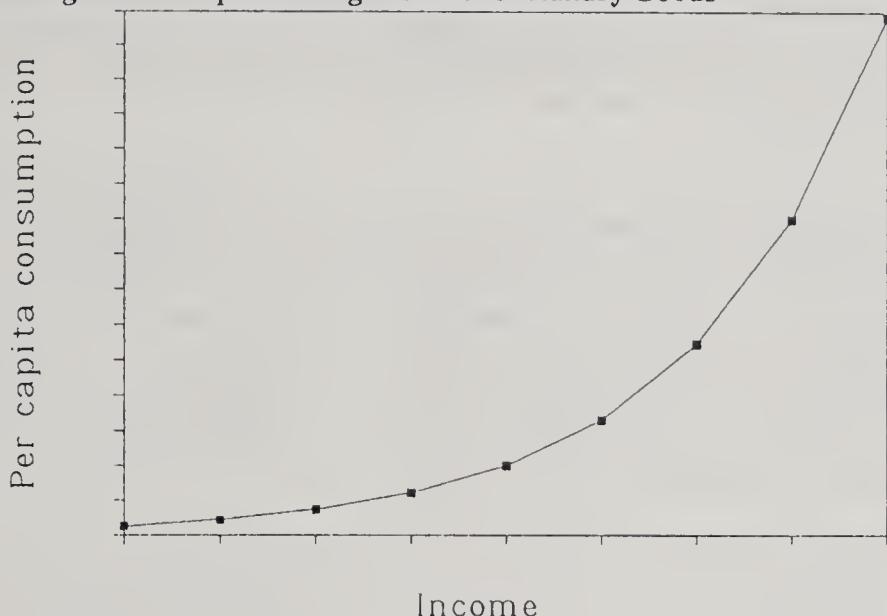
Income

MEASURING THE VARIABLES

The true measure of a nation's level of economic development is complex, involving such factors as income distribution, institutional growth, financial viability, and health care capacity. Unfortunately, few of these factors can be quantified reliably or grouped for comparison across many countries. However, since this study is concerned with measuring the level of economic development and its association with food demand across all countries, disposable income was the desired proxy variable. This variable was not available for many of the developing countries, forcing this study to use estimates of gross domestic product adjusted for purchasing power parity over the period 1961-81 in constant 1975 international dollars.2/ Use of the consistent GDP series constructed by Summers and Heston facilitates comparison across countries, including some centrally planned economies (19). To the extent disposable income remains a constant proportion of GDP, justification exists for substituting GDP for disposable income in consumption analysis. The GDP series was then converted to per capita terms using population data compiled by the Economic Research Service of USDA (21). Thus, real per capita GDP measured on a purchasing power parity basis will be used to measure economic development.

Food demand can be estimated in two ways: by using aggregate supply-utilization accounts and by using household budget surveys. Quantities available for human consumption are derived in the following manner from national supply-utilization accounts:

$$\text{Supply} = \text{Utilization}$$
$$\text{Supply} = \text{Production} + \text{Net Stock Changes} + \text{Net Imports}$$
$$\text{Utilization} = \text{Feed} + \text{Seed} + \text{Waste} + \text{Food}$$
$$\text{Production} + \text{Net Stock Changes} + \text{Net Imports} = \text{Feed} + \text{Seed} + \text{Waste} + \text{Food}$$

Food consumption is computed as a proportion of total supply through the use of extraction rates and is then balanced with the other variables in the equation.

2/ Further mention of per capita income will refer to constant 1975 international dollars. Due to the complexity and country specific nature of the purchasing power parity figures, updating the data to a more recent international dollar base, while desirable, was not done for this study as it will not change the basic research results. This updating will be attempted in future work.

The food balance procedure does not provide statistics on actual consumption because there are losses that occur in the distribution system, in food preparation, and at the table. In addition, consumption of home-produced food, which does not enter into the marketing system, often is excluded from the food-balance equation. On average, errors in measurement using this method understate actual consumption. But, if a systematic bias can be assumed, food balance consumption data adequately measure changes that occur over time.

Food consumption also can be measured by household budget surveys. Although household data are generally more detailed and complete regarding food consumption response to income changes at various levels of income distribution, there are several drawbacks to the use of such data for international comparisons. The major drawbacks are the limited number of countries where surveys have been completed and the lack of comparability across surveys. These surveys have traditionally collected data not on quantities purchased, but on expenditures for each commodity. Comparisons across countries become complex using expenditures as a basis because of differences in absolute and relative price levels between countries. Expenditures data may also include increasing costs of food processing or other services over the development process, as well as changes in the quantity consumed. As a result, quantities computed from expenditure surveys often overstate actual consumption (16).

This study uses food consumption quantities derived from The Food and Agriculture Organization's Food Balance Data Tapes. The data cover the period 1961-81 for 105 countries. To permit direct comparison among, and aggregation of, cereals in the study, the edible primary and secondary products of wheat, rice, maize, millet, barley, and sorghum were converted to wheat equivalent units.3/ Since the lack of price data precluded the computation of the Slutsky substitition matrix for determining separability of commodities, graphic analysis was used to indicate that separate demand functions exist for the three food groups. Thus, wheat and rice were grouped together, as were maize, millet, barley, and sorghum (referred to as coarse grains). Total meat also formed a separate group. Each of the commodity groups was then converted to kilograms per capita per year for use in the analysis.

Another measure of consumption was created, again using FAO data. This measure decribes calories of each food group as a percentage of total calories consumed per capita per day and is referred to as the percentage of total diet. The FAO series for total calories consumed country by country was available only from 1966-80, thus limiting this data set to those years.

ESTIMATION PROCEDURE

Discovery of separate demand functions for the three different food groups implies the existence of separable preferences. For the analysis to proceed as discussed in the theory chapter, the food groups must be classified as most preferred, preferred, or least preferred. The following preferences in the order of least to most preferred are assumed to hold: coarse grains; wheat and rice; and meat.

Separate demand functions require separate underlying utility functions for each of the food groups. The following utility tree helps to represent the commodity relationships:

3/ The process for conversion to wheat equivalent units is described as follows. Annual calorie data for the primary and secondary products of the individual food commodities were aggregated then divided by 2.53 million calories (1 metric ton of wheat = 2.53 million calories = 1 wheat equivalent unit) to arrive at a nation's annual consumption of that commodity in wheat equivalent units.

All commodities

Food   Nonfood

Least preferred   Preferred   Most preferred

Coarse grains   Wheat   Meat
/ Maize   \   Rice   / Beef and Buffalo \
(Millet   )   (Pork   )
(Barley   )   (Poultry   )
\ Sorghum   /   \ Sheep and Goat   /
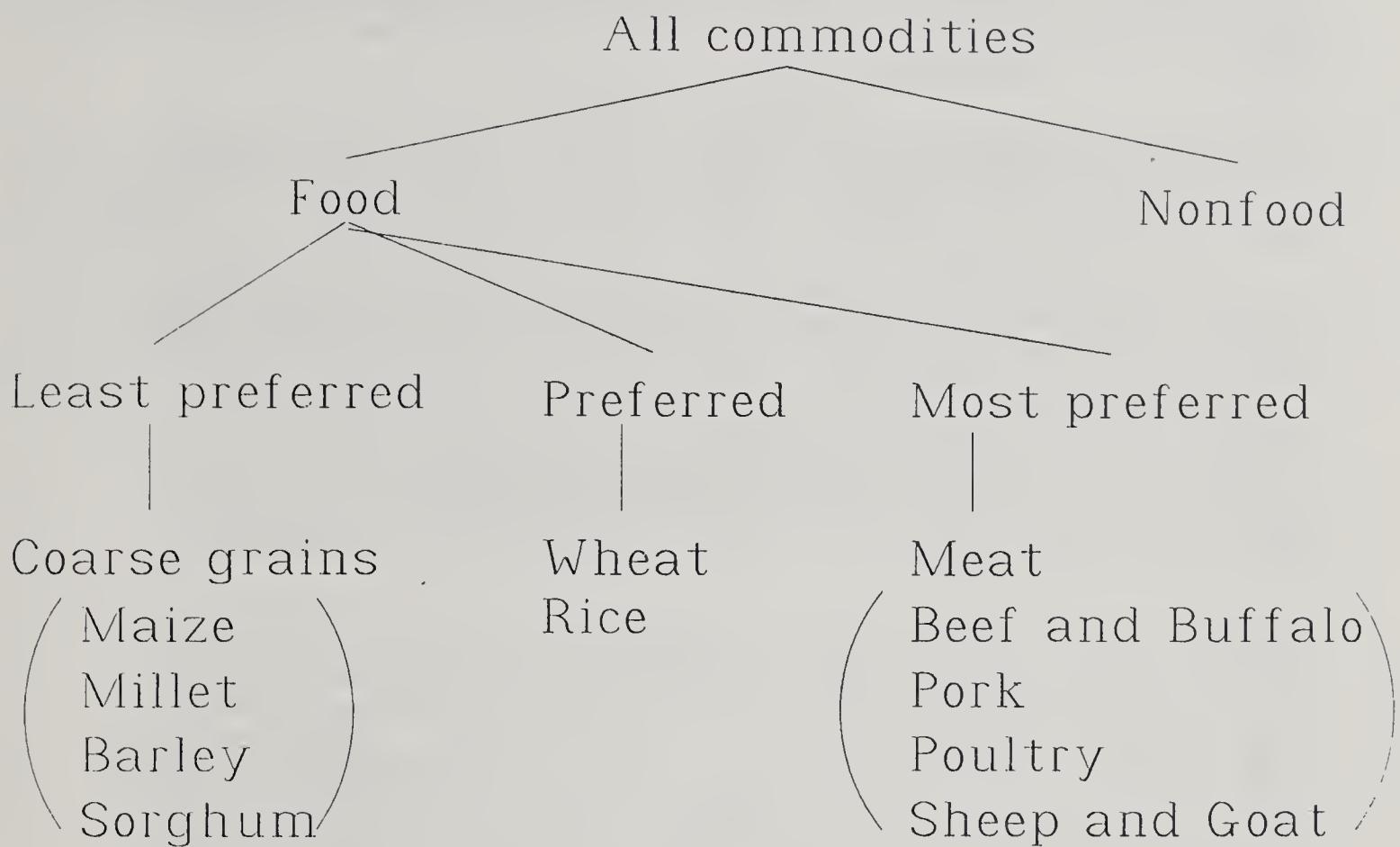
Since restrictions on behavior assuming strong separability rule out inferior and complementary commodities, the concept of weak separability is preferred for empirical work (2). Total utility for the food group with three weakly separable subgroups is described by equation 7, with general terms replaced by those referring to the three food groups:

(10) $$u = f\left[v_L\left(q_{ma}, q_{ml}, q_{ba}, q_{so}\right), v_P\left(q_{wh}, q_{ri}\right), v_M\left(q_{bf}, q_{pk}, q_{pl}, q_{sg}\right)\right]$$

where v_L = utility derived from maize, millet, barley, and sorghum

of the least preferred group L,

v_P = utility derived from wheat and rice of the preferred

group P,

v_M = utility derived from beef and buffalo, pork, poultry, and

sheep and goat of the most preferred group M.

The subutility functions, v_L, v_P, v_M, are maximized subject to the food budget constraint.

The preceding utility tree suggests that two-stage budgeting takes place, that consumers allocate their income first to a broad commodity group (food or nonfood) and second to individual commodities (wheat and rice, coarse grains, or meat). However, this hypothesis cannot be tested here because of insufficient information on nonfood consumption.

The expectation of separate commodity groups has been established. The substitution of per capita income for economic development, and of coarse grains, wheat and rice, and meat for least preferred, preferred, and most preferred foods, enables the statistical estimation of three demand equations associating per capita quantities demanded of each food classification with per capita income. Statistical significance of these equations would support or refute the hypothesized relationships.

Since sufficient and reliable price data do not exist for the commodities of this study, the traditional Marshallian demand function defined in equation 1 cannot be used. Instead, we assume that relative prices will remain constant, thus the Engel demand function defined in equation 5 will be estimated. If, in fact, prices should be included in the true equation, the demand model without prices is misspecified. Consequently, the estimated coefficient would be biased and inconsistent. The bias and inconsistency would disappear if prices and income are uncorrelated (13). Since prices in many of the study countries are not set by market forces but are determined instead by state policies, it is likely that prices have little correlation with income. But if prices are correlated with income in the study sample, then the variance of the estimated coefficient would be less than the variance of the true coefficient. This situation could lead to the acceptance of the estimated variable as significant when the true variable is not significant.

To determine the global demand function for 105 countries over a sufficient period of time to discern changing food demand patterns, the technique of pooling cross-sectional and time series data from 1961-81 for the 105 countries was employed. The technique assumes that each observation pairing income with consumption is independent of all other observations. This assumption is obviously too strong for the income observations within one country over time, and hence serial correlation almost certainly exists. Positive serial correlation often exists in time series analysis because of the cumulative effects over time. However, serial correlation will not affect the lack of bias nor the consistency of the ordinary least squares regression estimator, but affects the efficiency of the estimator. This loss of efficiency due to positive serial correlation would likely bias the standard errors of the regression downward, leading one to believe that parameter estimates are statistically stronger than they really are (13). The assumption of homoskedasticity, or constant error variance, most likely will be violated because of the large number of data points at the lower income range. Heteroskedasticity will also result in inefficient estimators. Correction for serial correlation and heteroskedasticity involve transformation of the data. However, since the objective of this study is to investigate general global patterns of consumption as a function of economic development, it seems appropriate to look directly at the relationship of income and consumption since this will facilitate interpretation of results.

The aggregation problem encountered when applying individual consumer demand theory to the use of average consumption data computed from aggregate national accounts will be ignored in this study. Aggregation error would not exist at all if one could assume that both income distribution and demographic composition remained constant over the estimation period.

The choice of functional forms for estimating demand equations must conform to both empirical evidence and to hypotheses about consumer behavior. Homogeneity, symmetry, and negativity constraints on the functional form are not applicable to equations in this analysis due to the assumed lack of relative price variation. Furthermore, the additivity constraint cannot be imposed since demand functions for the full set of consumption possibilities cannot be estimated; coarse grains, wheat and rice, and meat comprise an unknown percentage of the food budget.

For each food group and for each measure of consumption (percent of diet and annual kilograms per capita), the following functional forms were estimated:

1. $q = f(x)$
2. $q = f(x, x^2)$
3. $q = f(x, x^2, x^3)$
4. $\ln(q) = f(\ln(x))$
5. $\ln(q) = f(\ln(x), (\ln(x))^2)$
6. $\ln(q) = f(\ln(x), (\ln(x))^2, (\ln(x))^3)$

However, the equational forms specified in the following sections were found to fit the empirical data the best and to correspond to theoretical expectations.

Coarse Grains Demand Equation

Previous discussion leads to the expectation that as economic development proceeds, demand for the least preferred foods will fall in a nonlinear manner. To test this, an equation relating per capita quantities of coarse grains demanded to per capita income must be estimated. Analysis of coarse grain data suggested that this food group is economically inferior at all levels of income (fig. 4). Apparently, coarse grains are never considered a luxury item, or even a necessity, as incomes increase, contrary to the hypothesis that foods change from most preferred to preferred to least preferred items over the income spectrum. Thus, an equational form having a negatively sloped Engel curve would be appropriate. After trying several functional forms, a logarithmic equation was chosen on the basis of the best statistical fit.[4]

Figure 4 -- Coarse Grain Consumption [1]
(Scatter Graph of 105 Countries)
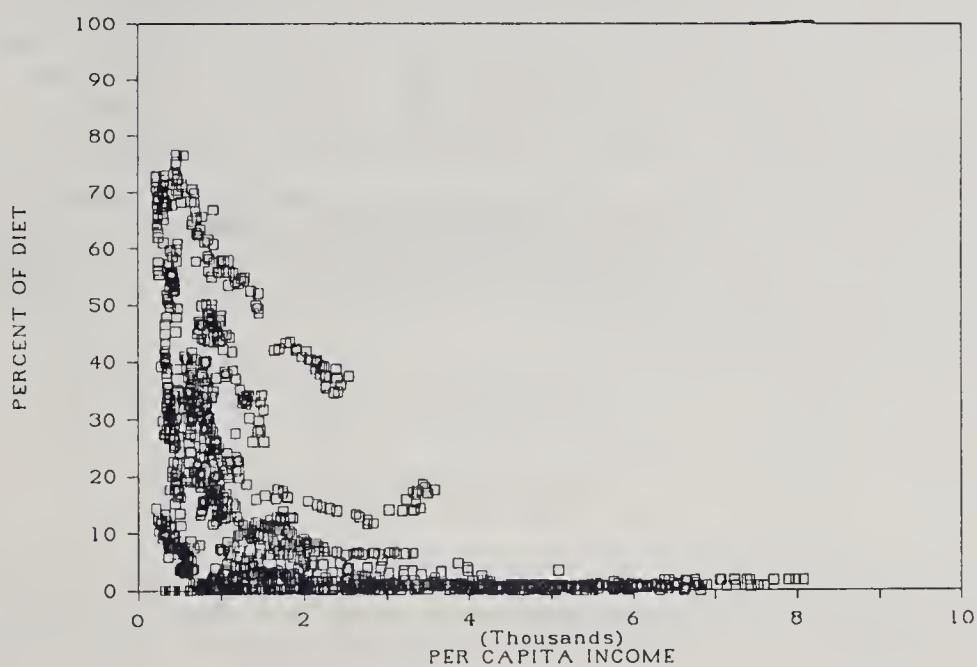
[1] The apparent zero values are a scale problem on the plot, not actual zero levels of consumption.

(11) $$\ln\left(q_{cg}\right) = \ln(\alpha) - \beta * \ln(x)$$

where q_{cg} = per capita consumption of coarse grains

x = per capita incomes

---

[4] Details of the statistical estimations are discussed in the "Results" section.

Significant results for the above equation would support the hypothesis that a negative nonlinear relationship exists between the quantity of least preferred foods and income.

The definition of the income elasticity of demand is the logarithmic derivative of the demand equation with respect to income. If the previously stated log-log demand functional form for coarse grains is statistically supported, then the resulting income elasticity will simply be a linear form, -B, over all income levels. In this case, the income elasticity of demand for least preferred foods will be a linear function of income.

Wheat and Rice Demand Equation

Following the discussion in the theory section, one would expect demand for foods to rise then fall as economic development proceeds, as foods change from most preferred to preferred to least preferred categories. Preliminary analysis of the wheat and rice data revealed two distinct country groups (see figures 5 through 7). An attempt to fit an equation to the data for all 105 countries resulted in a line that fell between the two groups, yet was unrepresentative of either group. A group of 80 countries clearly forms a pattern that follows expectations. Upon inspection of the 25 countries in the second group, these countries consumed much larger proportions of their diet as wheat and rice than countries in group one. Many of these countries subsidize consumption of either wheat or rice, causing consumption to be artificially higher than it normally would be. Although the group of 25 countries followed a pattern similar to that of the remaining 80, attempts to fit a smooth mathematical function to the data failed since the pattern is essentially discontinuous. Further analysis on this group will be undertaken at a later date. Since the group of 25 countries does not follow the general dominant pattern, this study will concentrate only on the group of 80 countries to determine the global pattern for wheat and rice consumption. (Appendix A provides a list of the countries in groups one and two.)

For the 80 countries, a third-order polynomial was needed to fit the curve through two evident inflection points and to allow for saturation of consumer demand. Intuitively, wheat and rice might be considered luxury goods at low income levels (compared with coarse grains), then become necessities as coarse grain consumption is reduced. Finally, wheat and rice may become an inferior good as meat is substituted into the diet. The hypothesized equation is:

$$(12) \qquad \ln\left(q_{wr}\right) = \ln(\alpha) + \beta * \ln(x) + \gamma * (\ln(x))^2 - \delta * (\ln(x))^3$$

$$\text{where } q_{wr} = \text{per capita consumption of wheat and rice}$$

Tests of significance of the estimated coefficients provide the information needed to support or refute the hypothesis of rising then falling demand for preferred foods as income levels increase. Other equational forms were investigated, such as linear and second-order polynomial models, but did not fit the data well.[5]

The income elasticity for the above equation would be nonlinear, having both increasing and decreasing ranges of elasticities as income increases:

$$(13) \qquad E_{wr} = \frac{\partial\left[\ln\left(q_{wr}\right)\right]}{\partial[\ln(x)]} = \beta + (2\gamma x) - \left(3\delta x^2\right)$$

_____

[5] Details of the statistical estimations are discussed in the "Results" section.

Figure 5 -- Wheat and Rice Consumption
(Scatter Graph of 105 Countries)
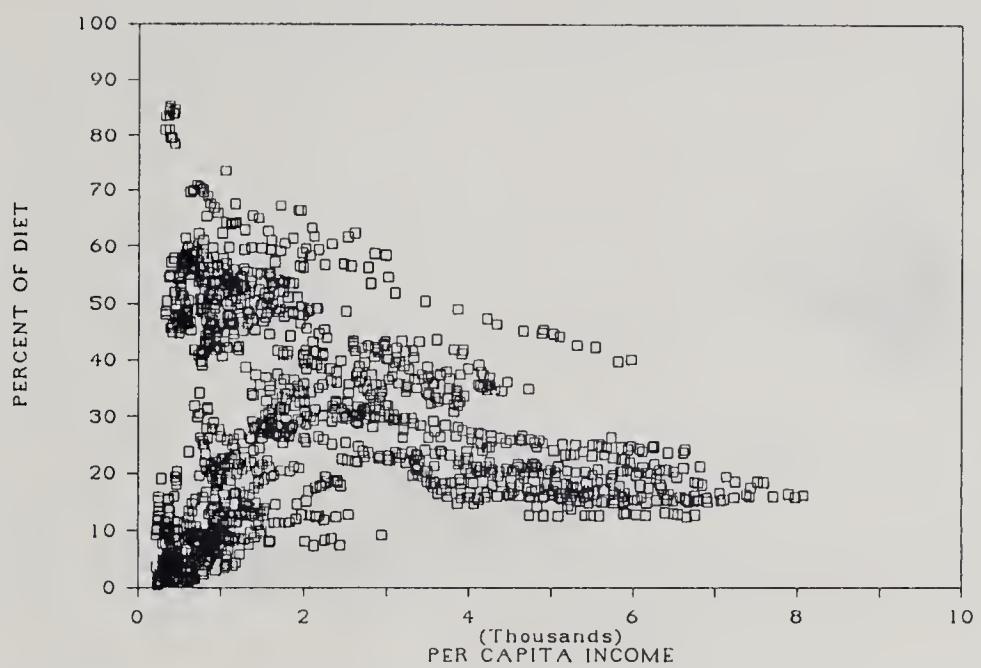
Figure 6 -- Wheat and Rice Consumption
(Scatter Graph of 80 Countries)

Figure 7 -- Wheat and Rice Consumption
(Scatter Graph of 25 Countries)

Figure 7 -- Wheat and Rice Consumption (Scatter Graph of 25 Countries). Y-axis: PERCENT OF DIET (0 to 100). X-axis: PER CAPITA INCOME (Thousands), 0 to 10.
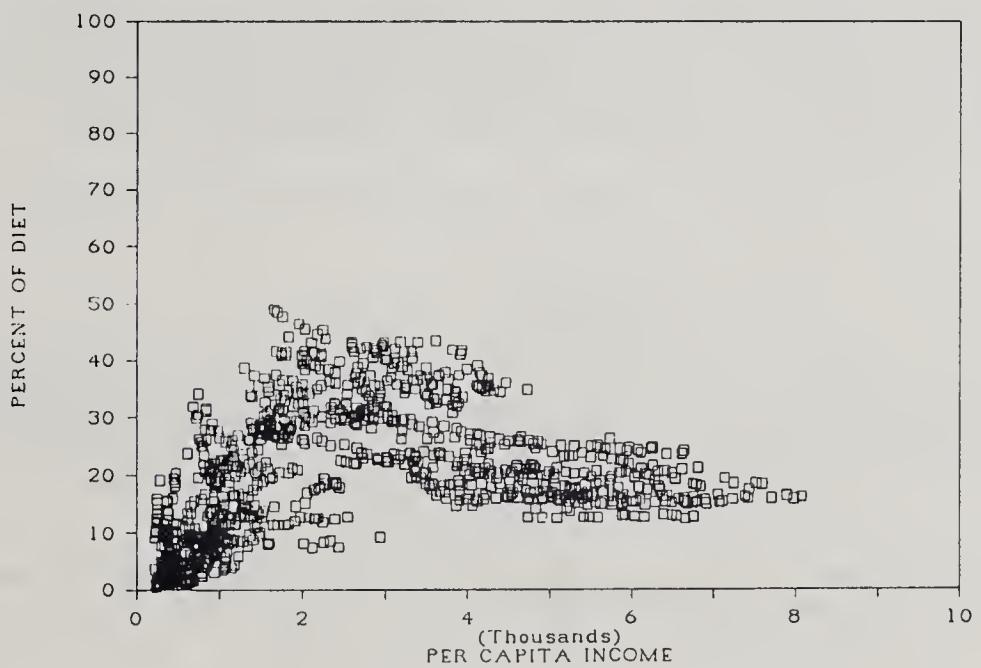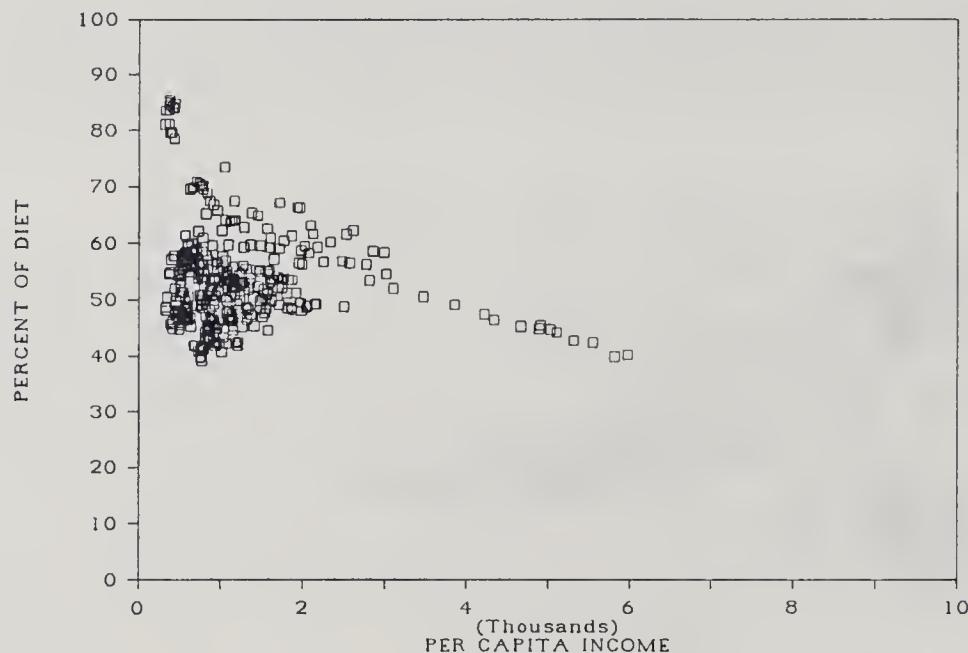
Meat and Meat Products Demand Equation

Meat consumption is assumed to follow a pattern similar to wheat and rice (fig. 8). We hypothesize that as economic development proceeds, demand for the most preferred foods will rise then fall in a nonlinear manner. Meat is thus considered a luxury at the low-income range. Then, at some income level the rate of increase in consumption decreases. Possible decreases in absolute meat consumption are envisioned as the variety of foods in the diet increases. Thus, the meat equation is another third-order polynomial:

$$(14) \qquad q_m = \alpha + (\beta * x) + \left(\gamma * x *^2\right) - \left(\delta * x^3\right)$$

$$\text{where } q_m = \text{per capita consumption of meat}$$

If the estimation procedure results in significant coefficients for the positive and negative variables, then there would be rising then falling portions of the demand curve for meat as incomes increase. Once again, other equational forms were investigated, but none were found to fit better than equation 14.[6]

Since the best statistical fit equational form for meat consumption is not a logarithmic function, the income elasticity is computed by applying equation 9, where $g_h = q_m$:

$$(15) \qquad E_m = \left(\frac{\partial q_m}{\partial x}\right) * \left(\frac{x}{q}\right) = \left[\beta + (2\gamma x) - \left(3\delta x^2\right)\right] * \left(\frac{x}{q}\right)$$

---

[6] Details of the statistical estimations are discussed in the "Results" section.

Figure 8 -- Meat Consumption
(Scatter Graph of 105 Countries)
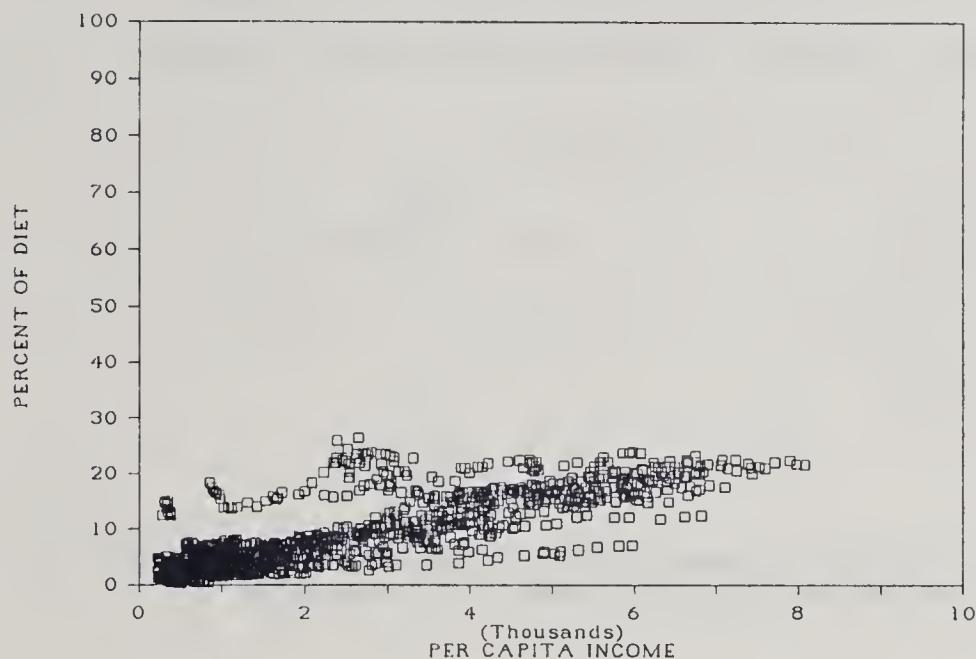
Substituting q_m for q:

$$(16) \qquad E_m = \frac{\left(\beta x + 2\gamma x^2 - 3\delta x^3\right)}{\left(\alpha + \beta x + \gamma x^2 - \delta x^3\right)}$$

With second- and third-order terms, this equation is nonlinear as income increases.

RESULTS

The general hypothesis of changing demand for food commodities as economic development proceeds is tested directly if dietary proportions of coarse grains, wheat and rice, and meat and meat products vary significantly with income level.

Coarse Grains Consumed as a Percentage of Diet

Coarse grains consumption, measured by percentage of diet as a function of per capita income, results in the following equational estimate (see figure 9 for a graph of the function):[7]

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[7] To graph the logarithmic equations on a nonlogarithmic scale, a correction factor equal to $e^{\sigma^2/2}$ was multiplied times the antilog of the estimated equation (see ([8]), pp. 400-402).

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(17)
$$\ln\left(q_{cg}\right) = \ln(\alpha) - \beta * \ln(x)$$

$$\ln\left(q_{cg}\right) = 11.7135 - 1.4216 * \ln(x)$$

where q_{cg} = percent of coarse grains in the diet

x = per capita income

	α	$\ln(x)$
t calculated	32.38	-28.68
t critical	1.645	-1.645

R^2 = .3614   Adjusted R^2 = .3610

F calculated: 1451.17
F critical: 3.84

S_e = 1.69

Figure 9 -- Statistical Best Fit Line for Coarse Grain Consumption
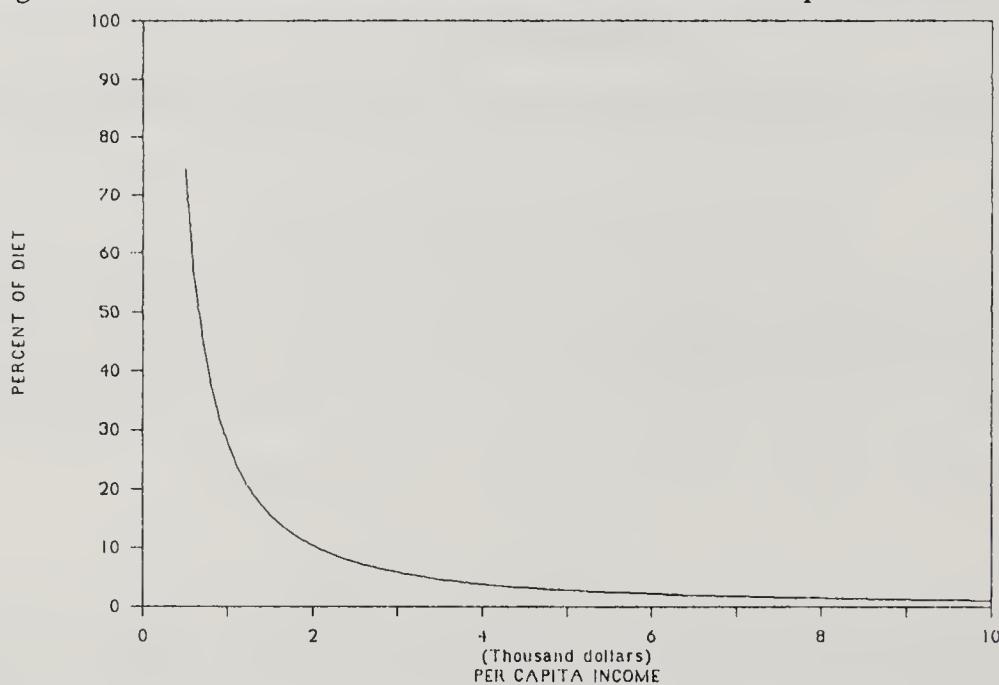
The 36 percent of the total variation in q_{cg} explained by the equation results in a computed F statistic that far exceeds the critical value.[8] Likewise, the t test for the significance of the regression coefficient resulted in a highly significant value.[9]

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[8] The magnitude of the R squared value would increase if Mexico and South Africa were dropped from the sample. However, the coarse grain data for these countries follow the same general shape as the global curve fit, but at a higher level of consumption. For this reason, they were retained in the database.

[9] For all F and t tests, a 95-percent confidence interval was used unless otherwise stated.

Therefore, the empirical evidence strongly suggests that the percentage of coarse grains in the diet decreases as income increases.

<div align="center">Wheat and Rice Consumed as a Percentage of Diet</div>

The estimated equation for wheat and rice as a percentage of diet and the summary statistics are presented below.

$$(18) \qquad \ln\left(q_{wr}\right) = \ln(\alpha) - \beta * \ln(x) + \gamma * (\ln(x))^2 - \delta * (\ln(x))^3$$

$$\ln\left(q_{wr}\right) = 91.4587 - 41.1988 * \ln(x) + 6.1596 * (\ln(x))^2 - .2982 * (\ln(x))^3$$

$$\text{where } q_{wr} = \text{percent of wheat and rice in the diet}$$

	α	$\ln(x)$	$(\ln(x))^2$	$(\ln(x))^3$
t calculated	12.39	-13.20	14.13	-14.84
t critical	1.645	-1.645	1.645	-1.645

$R^2 = .6034$ Adjusted $R^2 = .6024$

F calculated: 393.67
F critical: 2.6

$S_e = .51$

Figure 10 -- Statistical Best Fit Line for Wheat and Rice Consumption
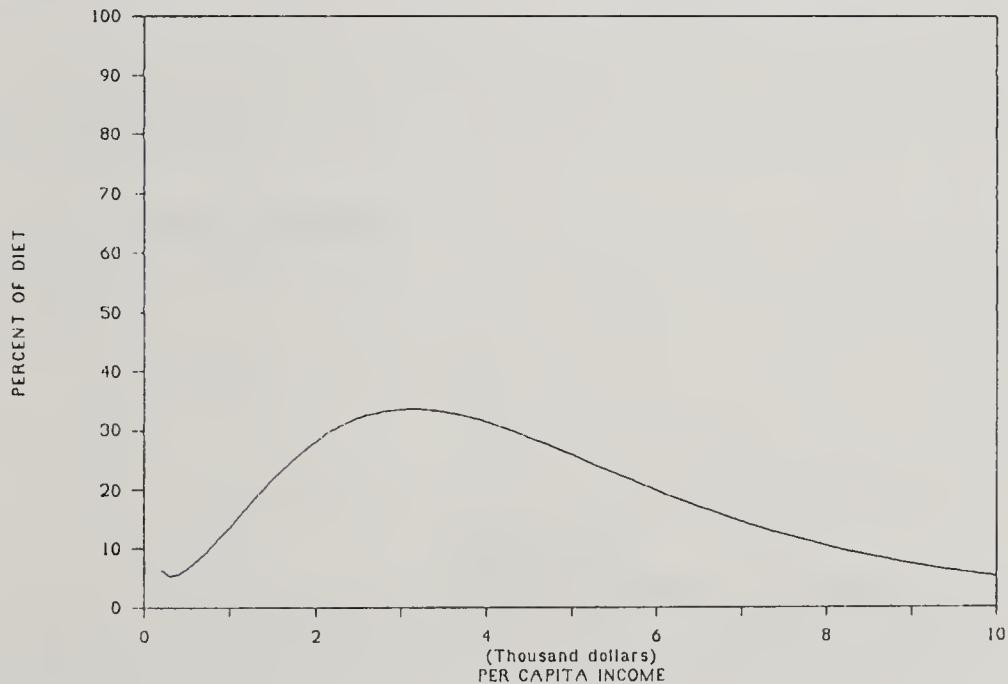
For this equation, each of the coefficients and the regression equation itself are significantly different from zero. Although the sign of coefficient B is negative, contrary to the expected positive value, a

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graph of the function shows the negative portion occuring at the extremely low income range (fig. 10). 10/ The curve fits the data well over all income levels. The percentage of wheat and rice in the diet, after an initial decrease, rises then falls as income increases.

Meat Consumed as a Percentage of Diet

The estimated equation for meat demand, measured as a percentage of diet, and the summary statistics are presented below.

$$(19) \qquad q_m = \alpha + \beta * x + \gamma * x^2 - \delta * x^3$$

$$q_m = 1.8432 + .0022 * x + .3563\,E-6 * x^2 - .4407\,E-10 * x^3$$

where q_m = percent of meat in the diet

	α	x	x^2	x^3
t calculated	6.33	5.30	2.49	-3.23
t critical	1.645	1.645	1.645	1.645

R^2 = .6768 Adjusted R^2 = .6762

Figure 11 -- Statistical Best Fit Line for Meat Consumption
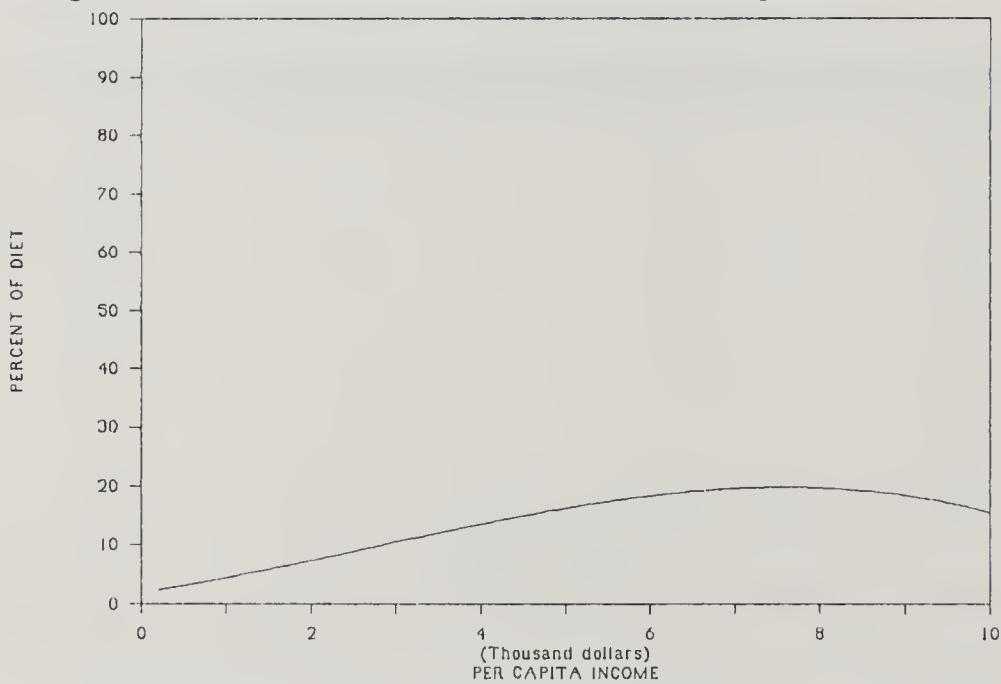
F calculated: 523.67
F critical: 2.6

S_c = 3.55

10/ The initial decrease may be a statistical anomaly caused by the chosen equation functional form, or may be an indication of consumers switching from lower quality grain to higher quality grain, such as from broken to whole rice. This issue will be examined in a future study.

Once again, the equation and all variables are significant. The significant positive first- and second-order terms indicate that the percentage of diet consumed as meat rose over a portion of the curve. The significant negative third-order term means that the curve fell at some point (fig. 11).

Quantity Demanded

Estimating quantity demanded as a function of income and computing the income elasticity of demand values provide additional insight.

Coarse Grain Quantities Demanded

The estimated equation for quantities of coarse grains consumed as a function of per capita income is:

$$(20) \qquad \ln\left(q_{cg}\right) = \ln(\alpha) - \beta * \ln(x)$$

$$\ln\left(q_{cg}\right) = 11.1690 - 1.1817 * \ln(x)$$

where q_{cg} = kilograms per capita per year of coarse grains.

	α	$\ln(x)$
t calculated	39.27	-30.04
t critical	1.645	-1.645

$R^2 = .3029$ Adjusted $R^2 = .3026$

F calculated: 5336.42
F critical: 3.84

$S_e = 1.60$

Both the equation and coefficients are significant. Quantities of coarse grains consumed decrease in a nonlinear manner as income rises.

Coarse Grain Income Elasticity of Demand

The income elasticity of demand for coarse grains is the logarithmic derivative of the estimated demand equation. Thus:

$$(21) \qquad E_{cg} = -\beta$$

or

$$E_{cg} = -1.1817$$

Since the best-fitting equational form for the demand function is a simple logarithmic form, the income elasticity for coarse grain demand is a constant value over all income levels and does not decline as income rises.

Wheat and Rice Quantities Demanded

The estimated equation for quantities of wheat and rice demanded as a function of per capita income is as follows:

$$(21) \quad \ln\left(q_{wr}\right) = \ln(\alpha) - \beta * \ln(x) + \gamma * (\ln(x))^2 - \delta * (\ln(x))^3$$

$$\ln\left(q_{wr}\right) = 73.8151 - 33.9304 * \ln(x) + 5.2152 * (\ln(x))^2 - .2566 * (\ln(x))^3$$

where q_{wr} = kilograms per capita per year of wheat and rice.

	α	$\ln(x)$	$(\ln(x))^2$	$(\ln(x))^3$
t calculated	11.17	-12.05	13.18	-13.96
t critical	1.645	-1.645	1.645	-1.645

R^2 = .6586 Adjusted R^2 = .6580

F calculated: 551.67
F critical: 2.6

S_e = .60

The equation and the coefficients are significantly different from zero. However, the sign of B is the opposite of the expected sign. A graph of the curve shows that a negative portion exists at the extreme low income range. However, after the initial decrease, the results indicate that quantities demanded of wheat and rice increase then decrease as income rises.

Wheat and Rice Income Elasticity of Demand

The income elasticity of demand is the logarithmic derivative of the estimated demand equation for wheat and rice:

$$(23) \quad E_{wr} = \beta + 2 * \gamma * x - 3 * \delta * x^2$$

or

$$E_{wr} = -33.9304 + 10.4304 * x - .7698 * x^2$$

Since the coefficient on income, x, is positive and on x^2 is negative, the curve of elasticities rises then falls as income rises.

Meat Quantities Demanded

The estimated equation for quantities of meat demanded as a function of per capita income are given below:

$$(24) \quad q_m = \alpha + \beta * x + \gamma * x^2 - \delta * x^3$$

$$q_m = 4.3651 + .0150 * x + .7654E-6 * x^2 - 1.7000E-10 * x^3$$

where q_m = kilograms per capita per year of meat.

	α	x	x^2	x^3
t calculated	4.00	9.32	1.36	-3.21
t critical	1.645	1.645	1.645	-1.645

R^2 = .6792 Adjusted R^2 = .6788

F calculated: 747.67
F critical: 2.6

$S_e = 16.31$

Although the coefficient on the second-order term is not significant, the significant positive first-order coefficient and the significant negative third-order coefficient indicate that quantities of meat consumed increase then decrease as income rises.

Meat Income Elasticity of Demand

The income elasticity of demand for meat is:

$$(25) \qquad E_m = \frac{\beta x + 2\gamma x^2 - 3\delta x^3}{\alpha + \beta x + \gamma x^2 - \delta x^3}$$

or

$$E_m = \frac{.02x + .03x^2 - .02E-4x^3}{4.37 + .02x + .77E-6x^2 - 1.7E-10x^3}$$

A graph of this equation would show that the income elasticity value for meat increases then decreases as income rises.

Summary of Findings

The estimated functions and statistical results of the equations for each of the three food groups show that as income increases: the percentage of coarse grains in the diet decreases; the percentage of wheat and rice in the diet increases then decreases; and the percentage of meat in the diet increases then decreases. Quantities demanded and the income elasticities of demand for both wheat and rice and meat rise then fall as income increases. Coarse grain quantities demanded decrease in a nonlinear manner as income rises. Contrary to the hypothesis, the income elasticity of demand for coarse grains remains constant; it is not a nonlinear function of income.

IMPLICATIONS

This study has shown that percentages of coarse grains, wheat and rice, and meat in the diet each vary significantly with per capita income. The estimated food demand functions enable anticipation of the direction and magnitude of changes over the observed income range. Thus far, each food group has been analyzed separately. Since the diet is composed of many foods, the consumption of one type of food often affects quantities consumed of other foods. Commodities may be either substitutes or complements for each other. Since we have shown that consumption of wheat and rice, and meat both increase then decrease, the analysis seems incomplete without investigating ranges of complementarity and substitutability. [11]

In this section, all three food groups will be analyzed together to determine demand patterns that describe the changing mix of food commodities in the diet at each income level. Particular demand patterns can then be associated with ranges of income levels, or stages of economic development. These stages of economic development hold important consequences for trade potential.

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[11] Statistical tests to verify that commodities are substitutes or complements require the use of cross-price elasticities. Since this study was unable to calculate price elasticities, reference to "substitute" or "complement" is only in the general sense, not the statistical econometric sense.

As income increases, less preferred foods are replaced in the diet by foods ranking higher in consumers' preference hierarchy. Figure 12, which graphs simultaneously the demand functions for each of the three food groups studied, shows adjustments that take place among coarse grains, wheat and rice, and meat.

Figure 12 -- Food Consumption/Percentage of Diet for Wheat and Rice, Meat, and Coarse Grains
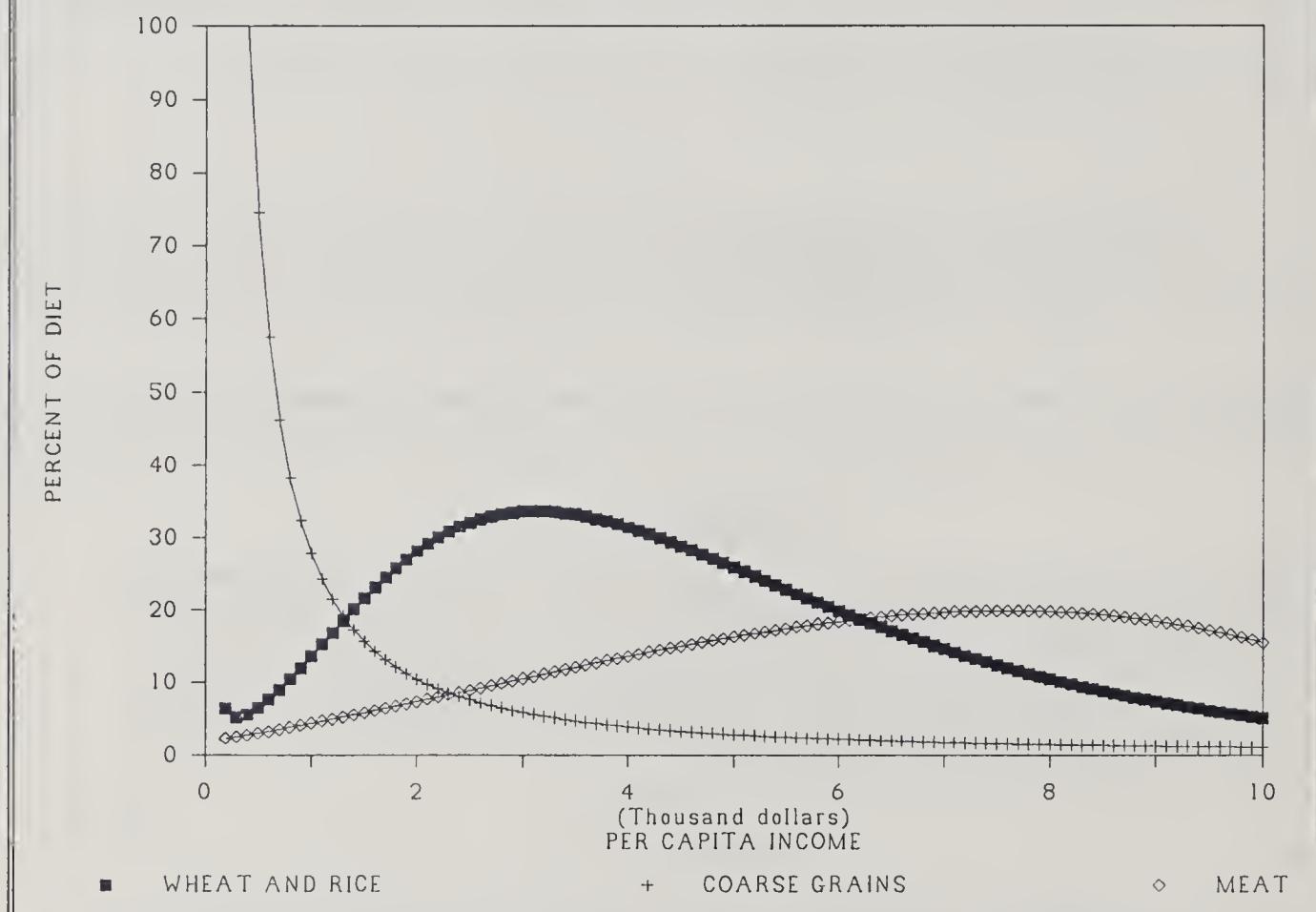
Although preferences may differ among countries, enough commonalities exist globally to support earlier statements about the preference order from least to most preferred: coarse grains, wheat and rice, and meat. At low income levels, coarse grains account for a large proportion of the diet. But as incomes rise, the percentage of coarse grains in the diet decreases rapidly and is overtaken by wheat and rice. As income reaches a high level, the proportion of meat in the diet exceeds that of wheat and rice. It appears that wheat and rice substitute for coarse grains at lower income levels, and then, at higher incomes, meat substitutes for wheat and rice in the diet. From approximately $300 to $3,100, consumption of meat products and wheat and rice complement each other.12/ These food demand shifts have been acknowledged in studies by Poleman, Mellor, Delgado and Miller, and others (16, 10, 4).

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12/ Income is measured in 1975 constant international dollars and is adjusted for purchasing power parity.

Stages of Economic Development

Income ranges can be identified with particular food demand patterns, measured by the portion of a given food in the diet. These patterns describe six stages of economic development (fig. 13). Stage I is defined from the beginning of the data range to the intersection of the coarse grains and wheat and rice curves. Stage II begins at that intersection and continues to the crossing of the coarse grains and meat curves. From that crossing to the maximum point of the wheat and rice curve, stage III is defined. Stage IV continues from the maximum point of the wheat and rice curve to the intersection of the meat and wheat and rice curves. Stage V proceeds from there to the maximum point of the meat curve. Finally, stage VI continues from the maximum of the meat curve to the end of the data range.

Figure 13 -- Stages of Economic Development Seen in Shares of Wheat and Rice, Meat, and Coarse Grains in the Diet
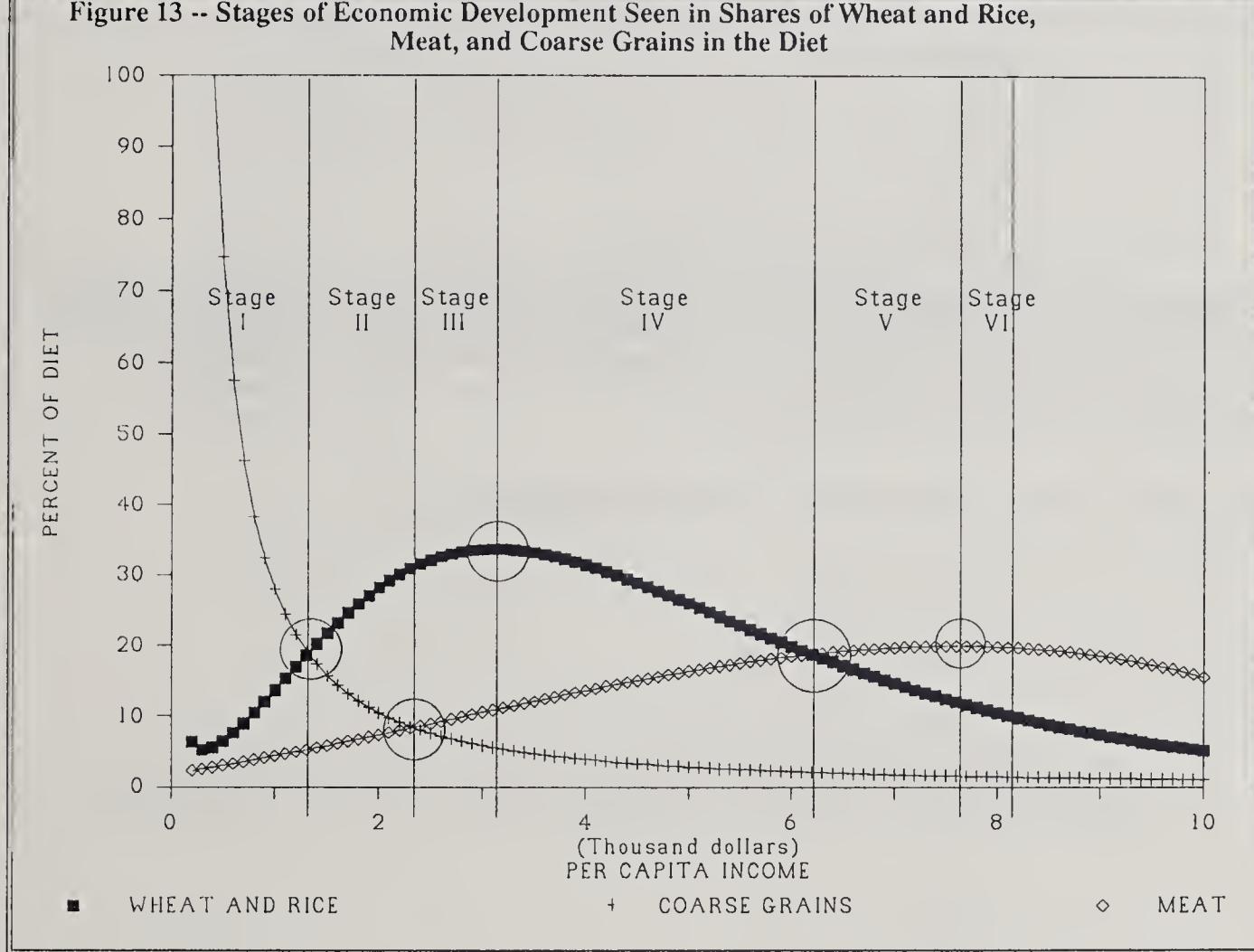
Though this study does not focus on the projection of food demand patterns, it seems reasonable to expect individual countries to follow the global patterns exhibited in figure 13, and described in the following paragraphs. Unless special climatic or cultural circumstances cause major departures from the patterns, we expect most deviations to be transitory. For example, in Japan "the starchy staple ratio dropped from 75 to 55 percent, and proteins of animal origin rose from less than 25 percent of the total to almost half" in recent years (16). This implies that as incomes in Japan continue to increase, demand patterns will quickly approach the global patterns.

Low-Income Stages

Developing countries in the lower income ranges modify their food commodity mix as economic development proceeds by replacing traditional foods in the diet, such as coarse grains (and probably also roots and tubers) with wheat and rice (4). Thus, demand pattern adjustments occur among the staple commodity groups.13/ For countries in the lowest income range, meat is not in the effective field of choice. In these countries, consumers are still too poor to effectively demand more than the cheapest food commodities. But, as incomes rise past $300, meat enters the effective field of choice and complements wheat and rice.

Stage I. In the lowest income range, defined from approximately $200 to $1,300, demand patterns are characterized by the following commodity group relationships:

a. $q_{cg} > q_{wr} > q_m$

b. $\dfrac{\partial q_{cg}}{\partial x} < 0$

c. $\left(\dfrac{\partial q_{wr}}{\partial x} > 0 \right) > \left(\dfrac{\partial q_m}{\partial x} > 0 \right)$

The first relationship states that coarse grains consumption as a percentage of diet is greater than wheat and rice consumption, which is greater than meat consumption. Second, the rate of change in coarse grain consumption decreases for an increase in income. And third, the rate of increase of wheat and rice consumption is greater than that of meat consumption. At approximately $1,300, coarse grains consumption equals wheat and rice consumption.

Stage II. From $1,300 to approximately $2,300 the following relationships exist:

a. $q_{wr} > q_{cg} > q_m$

b. $\dfrac{\partial q_{cg}}{\partial x} < 0$

c. $\left(\dfrac{\partial q_{wr}}{\partial x} > 0 \right) > \left(\dfrac{\partial q_m}{\partial x} > 0 \right)$

d. $\dfrac{\partial^2 q_{wr}}{\partial x^2} < 0$

e. $\dfrac{\partial^2 q_m}{\partial x^2} > 0$

These relationships permit the following statements to be made. The share of wheat and rice in the diet exceeds that of coarse grains and of meat. Coarse grains consumption continues to decrease. The rate of increase in wheat and rice consumption is greater than the rate of increase in meat consumption. Wheat and rice consumption increases at a decreasing rate, while meat consumption increases at an increasing rate. The percentage of diet consumed as coarse grains equals meat consumption at $2,300.

13/ Consumption pattern adjustments may also occur between various qualities within one commodity group. For example, substitution takes place between rice of various qualities in South and Southeast Asia (15).

Middle-Income Stages

As countries pass through the middle-income ranges, wheat and rice consumption peaks and then decreases. Substitution of animal products (such as meat) for grains (such as wheat and rice, and coarse grains) takes place. The rise in meat demand continues until high-income levels are reached.

Stage III. Incomes from about $2,300-$3,100 are characterized by:

a. $q_{wr} > q_m > q_{cg}$

b. $\dfrac{\partial q_{cg}}{\partial x} < 0$

c. $\dfrac{\partial q_{wr}}{\partial x} > 0 \; ; \dfrac{\partial q_m}{\partial x} > 0$

d. $\dfrac{\partial^2 q_{wr}}{\partial x^2} < 0 \; ; \text{ after } \$2,700 \; \dfrac{\partial^2 q_m}{\partial x^2} < 0$

Wheat and rice account for the largest share in the diet, followed by meat and coarse grains. The percentage of coarse grains in the diet continues to decrease. While meat and wheat and rice consumption increase, they increase at a decreasing rate. Wheat and rice consumption as a percentage of diet reaches a maximum at $3,100.

Stage IV. From $3,100-$6,200:

a. $q_{wr} > q_m > q_{cg}$

b. $\dfrac{\partial q_{wr}}{\partial x} < 0 \; ; \dfrac{\partial q_{cg}}{\partial x} < 0$

c. $\dfrac{\partial q_m}{\partial x} > 0 \; ; \dfrac{\partial^2 q_m}{\partial x^2} < 0$

Consumption of wheat and rice is greater than for meat, which is greater than for coarse grains. Both coarse grains and wheat and rice have declining consumption percentages. Meat consumption is increasing, but at a decreasing rate. The percentage of meat consumption equals wheat and rice at $6,200.

High-Income Stages

Meat consumption as a percentage of the diet surpasses wheat and rice consumption at approximately $6,200 in the high-income range representing developed market economies. However, the share of meat in the diet tends to reach a saturation point, and even declines at extreme high-income levels. This result is supported by Sarma and Yeung in (18) and by Blandford in (1).

Stage V. At income levels from $6,200-$7,600:

a. $q_m > q_{wr} > q_{cg}$

b. $\dfrac{\partial q_{wr}}{\partial x} < 0 ; \dfrac{\partial q_{cg}}{\partial x} < 0$

c. $\dfrac{\partial q_m}{\partial x} > 0 ; \dfrac{\partial^2 q_m}{\partial x^2} < 0$

In this income range, meat consumption surpasses that of wheat and rice, which is greater than that of coarse grains. Both wheat and rice and coarse grains continue to decline in the diet. Meat consumption rises at a decreasing rate, reaching a maximum at $7,600.

Stage VI. Incomes from $7,600 to the end of the data range, $8,100, are characterized by:

a. $q_m > q_{wr} > q_{cg}$

b. $\dfrac{\partial q_m}{\partial x} < 0 ; \dfrac{\partial q_{wr}}{\partial x} < 0 ; \dfrac{\partial q_{cg}}{\partial x} < 0$

In this stage, the proportion of the diet accounted for by meat is the greatest, followed by wheat and rice and coarse grains. All three groups decline as income increases.

The Relationship Between Income and Nutrition

The shifts in food demand that occur as incomes increase allow preferred foods to replace less preferred foods in the diet. Underlying the preference order is the assumption that consumers desire to improve the quality of their diets. Whether this subjective quality increase results in improved nutritional intake remains uncertain.

To investigate this issue, a measure of nutritional status was calculated by dividing the Food and Agriculture Organization/World Health Organization's recommended daily per capita caloric requirement level for a country by daily per capita total calories consumed, creating a data series for the years 1966-80. This measure is called "the percent of recommended daily allowance for total calories," or percent RDA. Figure 14 is a scatter graph showing the relationship between percent RDA and per capita income. The relationship appears sharply positive up to approximately $4,000, where percent RDA peaks at around 120 percent.

Figure 14 -- Relationship Between Income and Percentage RDA 1/
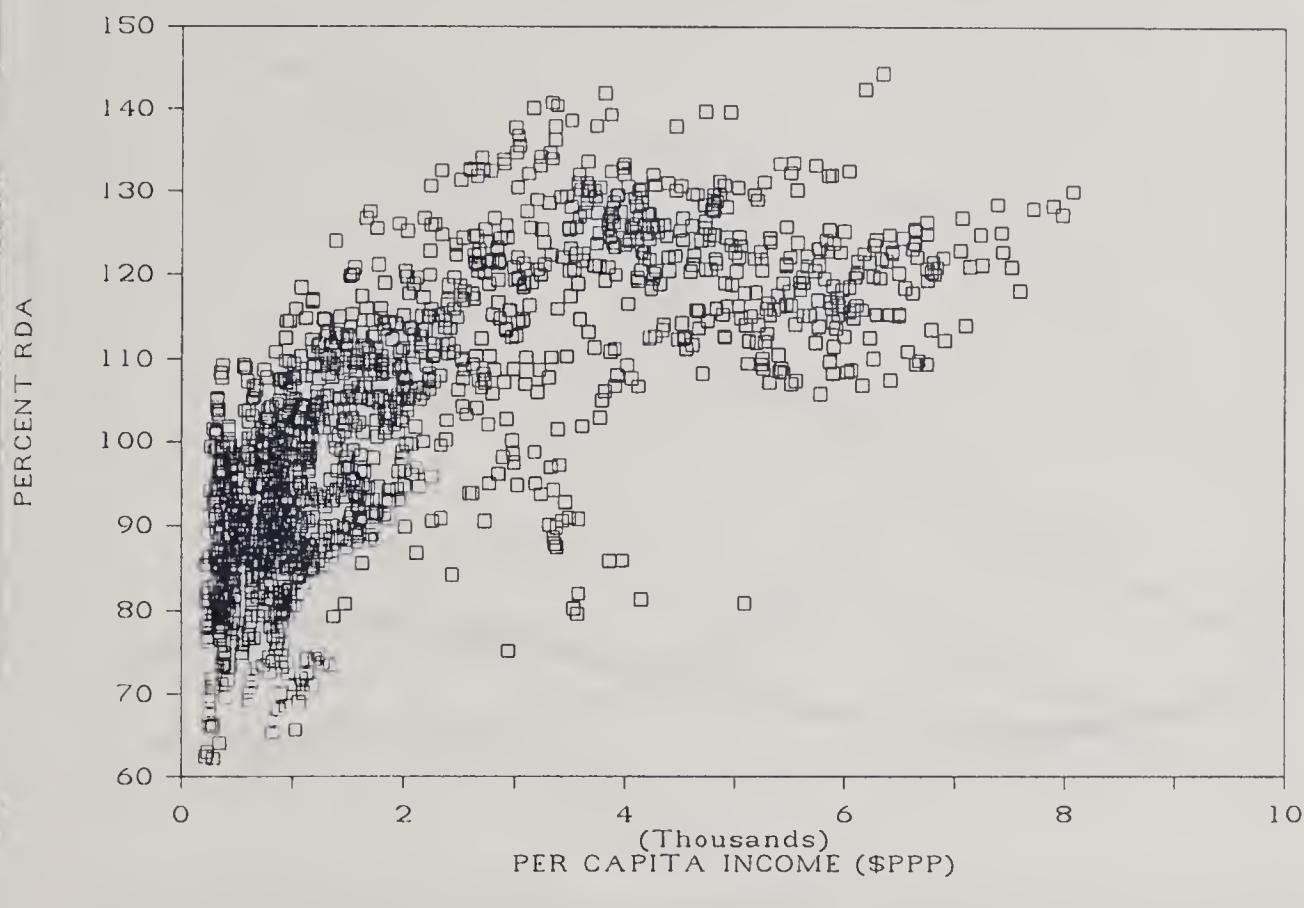
1/ RDA is recommended daily allowance.

Figure 15 shows the resulting curves from regression analysis of each food group as a function of percent RDA.14/ However, several interesting facts are noted in the income range depicting the sharply positive income/percent RDA ratio. The intersection of the coarse grains curve with the wheat and rice curve occurs at approximately 100 percent RDA. That is, when consumption of coarse grains and wheat and rice are at equal proportions in the diet, consumers are at the point of nutritional caloric adequacy. These results were anticipated by Poleman who stated: "One of the first changes evident in 19th Century Europe was the replacement of rye bread and potatoes by wheat products, and a shift away from maize meal marked the onset of the transformation of the American diet. If one were to seek a behavioral threshold suggestive of perceived nutritional adequacy, then, a prima facie case can best be made for the income level at which this type of substitution sets in" (16). The income level at which this substitution of coarse grains for wheat and rice occurs is approximately $1,300, which suggests that $1,300, in 1975 purchasing power equivalents, is the income threshold for dietary caloric adequacy.

14/ See Appendix B for equation estimates.

Figure 15 -- Food Consumption Versus Percentage RDA
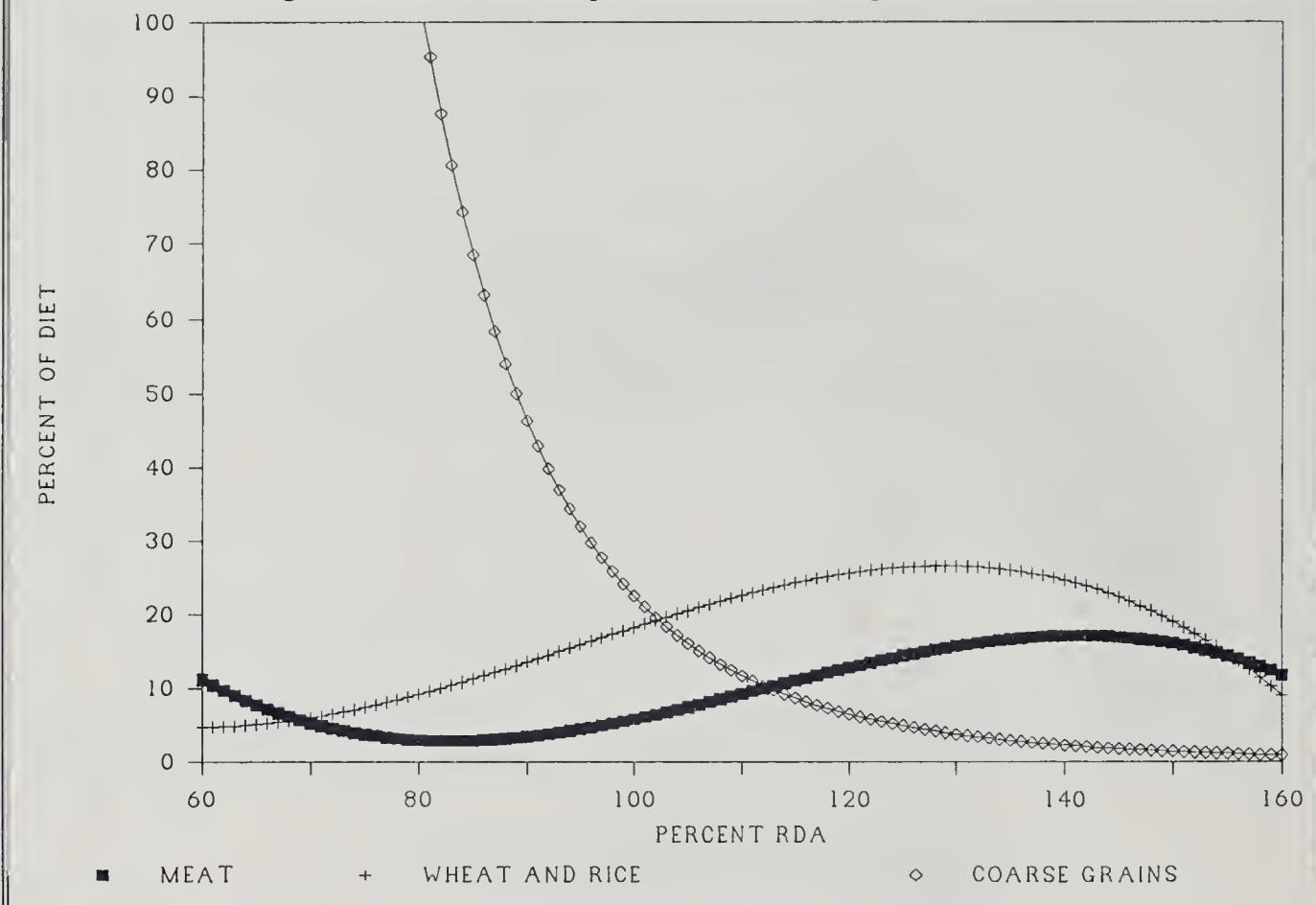
The stages of economic development may also be imposed upon figure 15. In stage I, incomes from $200-$1,300 would correspond to 60-100 percent RDA. Stage II, from $1,300-$2,300 corresponds to 100-110 percent RDA. And in stage III, incomes from $2,300-$3,100 correspond to 110-130 percent RDA. Stages IV, V, and VI occur on the plateau of the income/percent RDA ratio.

Income Elasticity of Demand Patterns

Poleman suggested that an exception to Engel's Law exists when consumers perceive that they are below the dietary adequacy threshold (16). Engel's Law requires income elasticities to decline over increasing levels of income. However, according to Poleman, starving people would use a 1-percent increase in income to increase food consumption by more than 1-percent. This suggests that they would increase the percentage of income alotted to food consumption by reducing the percentage for nonfood consumption. Thus, increasing elasticities of demand would exist at the extreme low-income level. Once the consumer perceives that he has reached an adequate diet, Engel's law would then begin to evidence itself. A decreasing percentage of the budget for a 1-percent increase in income would be spent on food.

Figure 16 shows the income elasticities of demand for the three food groups. The results indicate that a range of increasing elasticities exists at the extreme low-income level for wheat and rice and for meat. Regier and Goolsby found similar results for meat elasticities (17). The point of inflection for wheat and rice occurs at approximately $1,000 and for meat at approximately $1,400, which corresponds closely to the dietary adequacy level found in the last section. This may be the "poverty line" referred to by Poleman.

Figure 16 -- Food Commodity Income Elasticities of Demand
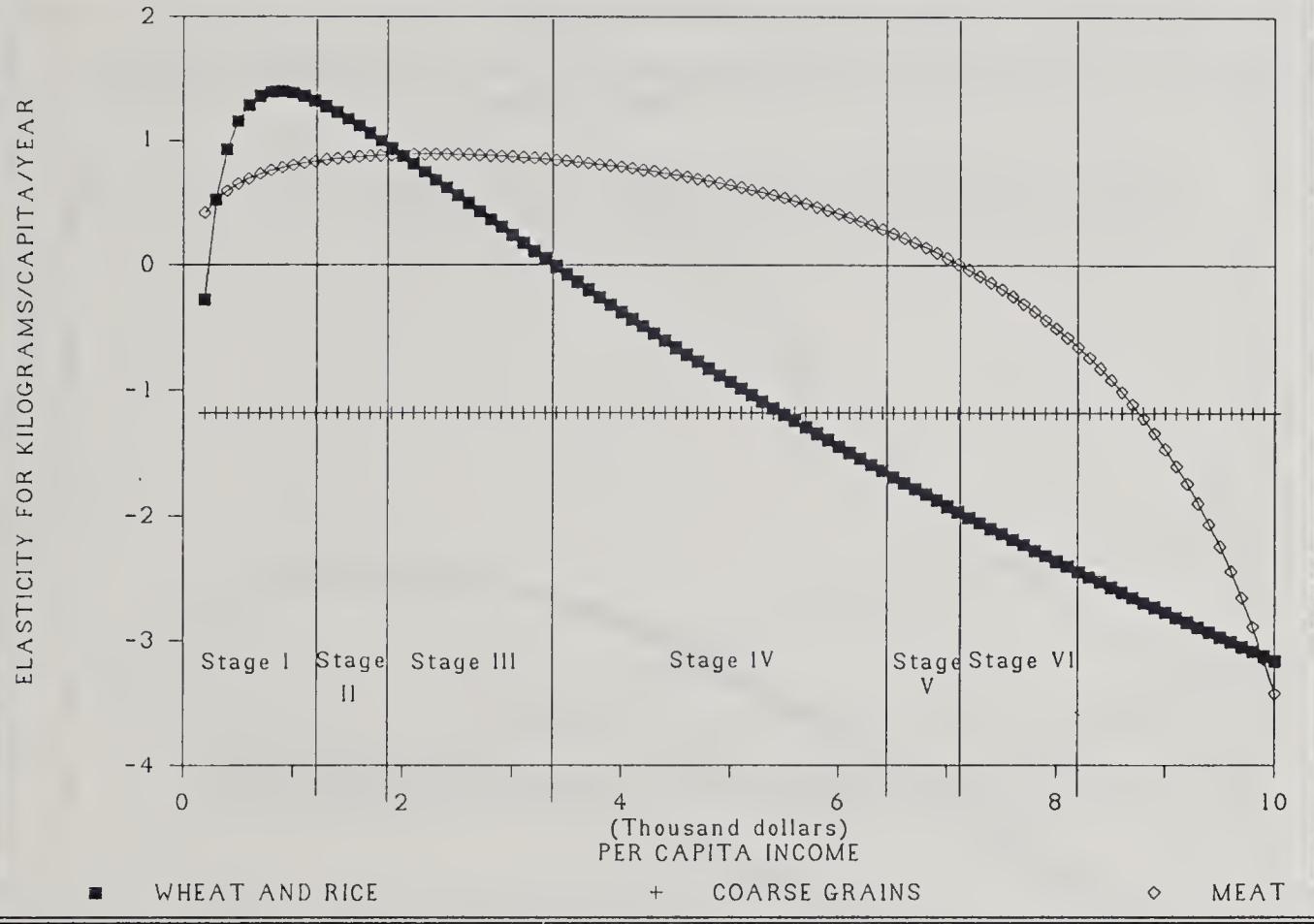
Elasticity values for wheat and rice from about $500-$1,800 are greater than one, indicating that wheat and rice are a luxury in this income range. The maximum value is 1.4, which means that consumers will increase wheat and rice consumption 14 percent for a 10-percent increase in income. From $1,900 to the end of the data range ($8,100), wheat and rice elasticities of demand decline, thus conforming to Engel's Law. The elasticity values are between 0 and 1 from $1,900-$3,300. These values indicate that wheat and rice are economic necessities in this range. However, wheat and rice become economically inferior goods as incomes rise past $3,400.

Income elasticities of demand for meat reach a maximum value of approximately 0.9. This means that consumers will increase the quantity of meat consumed by 9 percent for a 10-percent increase in income. The elasticity value remains nearly constant until about $3,300, after which it begins to decline. But meat does not become an inferior good until very high incomes above $7,200 are attained.

The income elasticity of demand for coarse grains is a constant negative value over all income levels. For a 10-percent increase in income, coarse grains consumption will decrease 12 percent. Thus, coarse grains consumed as food are defined as economically inferior goods.

<u>Meat Consumption Patterns</u>

Since coarse grains used for animal feed account for a major proportion of U.S. agricultural exports, an analysis of the global demand for meat provides information about the derived demand for feed grains.

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Various livestock enterprises have quite different implications for feed grain demand. Therefore, the same theory, methodology, and empirical analysis were used to investigate the meat subgroups: beef and buffalo (referred to as beef); poultry; pork; and sheep and goat.15/

Figure 17 summarizes the relationships among the meat groups at different income levels. Figure 18 shows the individual meat categories in relation to the two grains groups.

Figure 17 -- Statistical Best Fit Lines for Meat Consumption
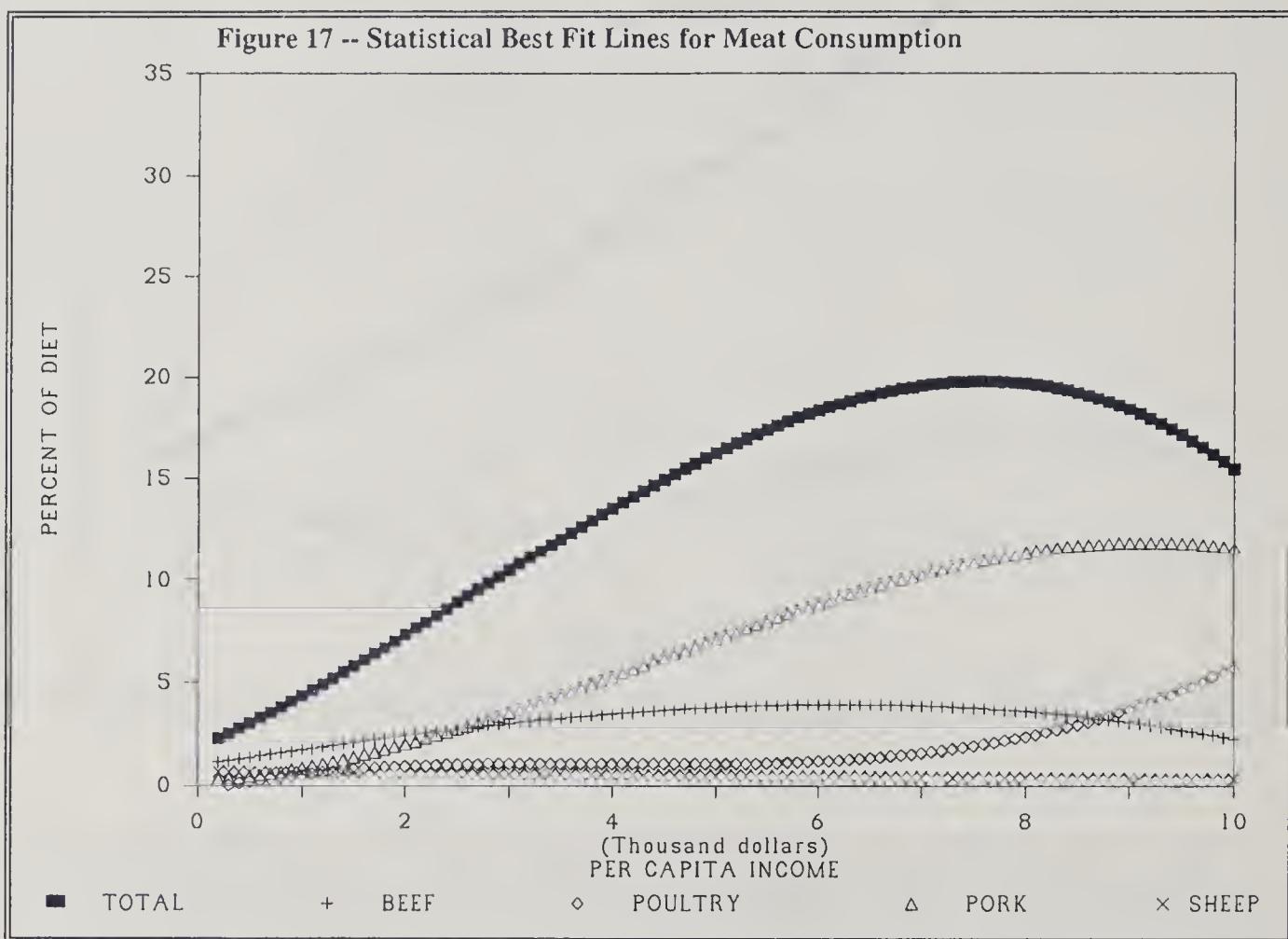
In terms of demand measured as a percentage of diet, the preference order from least to most preferred at the highest income level appears to be sheep and goat, poultry, beef, pork. Percentages in the diet of pork are increasing at the end of the data range, but at a decreasing rate. This suggests that pork consumption is near a saturation point and will probably decline as incomes rise. The share of beef and buffalo consumption in the diet reaches a maximum at approximately $6,200, then declines. After that income level, the percentage of poultry consumed in the diet begins to rise rapidly, implying that poultry and beef are substitutes. Sheep and goat meat as a percentage of diet decreases over all income ranges.

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15/ Results of the equation estimations are found in Appendix C.

Figure 18 -- Meat Categories Comparison with Grains
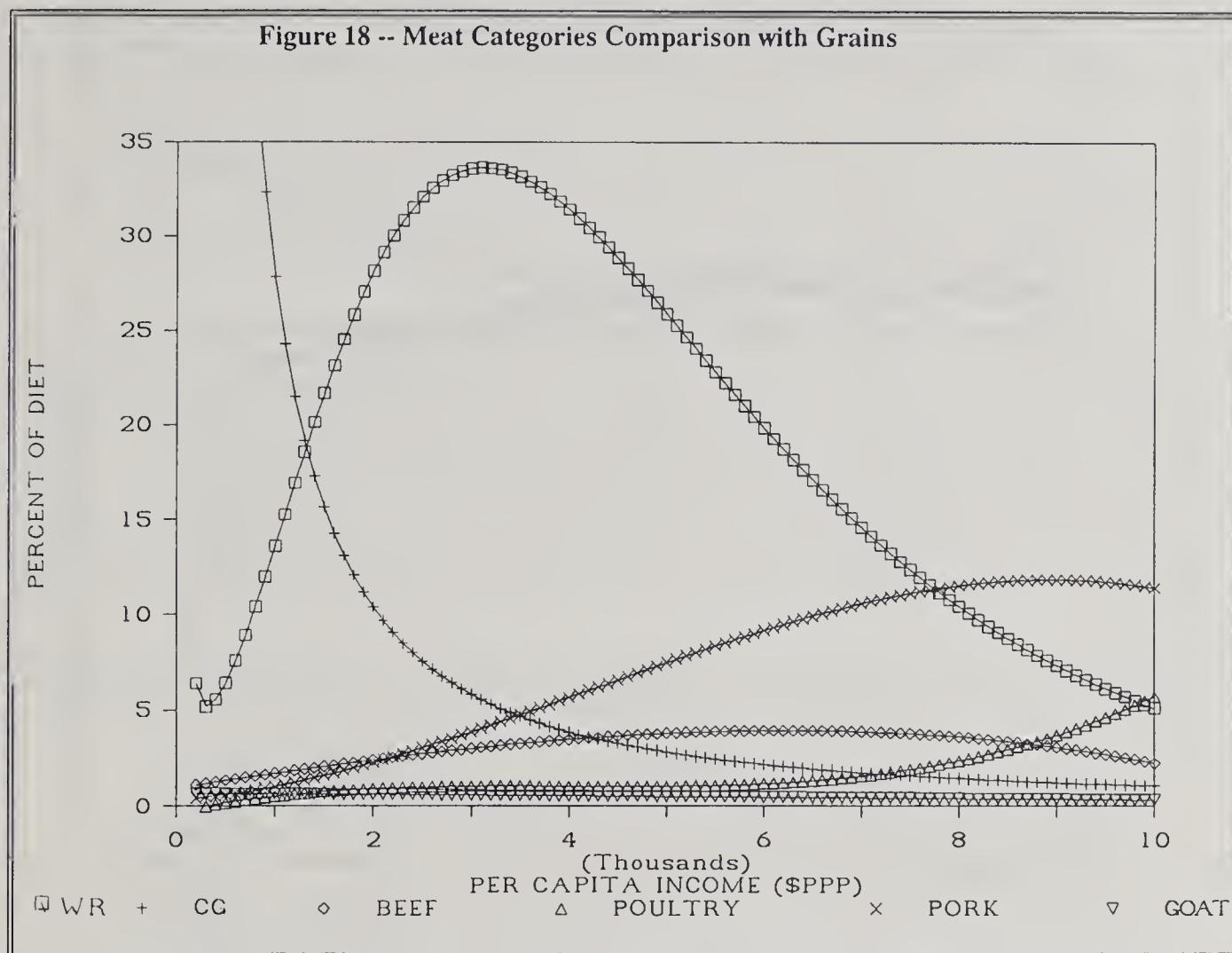
Figure 19 illustrates the income elasticities of demand derived from the equations associating per capita quantities consumed for each meat group with per capita income. The elasticity for sheep and goat meat is near zero over all income levels, indicating quantity consumed is not responsive to income changes. Both beef and pork have ranges of increasing elasticities at extreme low-income levels. This means that a 1-percent increase in income will lead to a greater than 1-percent increase in demand for pork and beef throughout this range. Increasing elasticities for beef and pork occur in the range where the poultry elasticity is falling sharply. This suggests that both beef and pork are substitutes for poultry at low-income levels. However, at approximately $4,000, the poultry elasticity begins to rise and continues to rise over increasing incomes. This dichotomy implies that consumers perceive poultry as a relatively inferior good at low-income levels, but as a luxury good at higher incomes. Possibly, poultry consumed at low-income levels (which is often tough and stringy) is a different good from the higher quality poultry that is raised in confinement, nourished on concentrated feeds, and consumed at higher incomes. Both beef and pork are considered economically inferior goods after approximately $6,800. Exactly why this occurs would be an interesting study in itself. However, one may conjecture that health concerns about fat intake and cholesterol have led consumers to reduce beef and pork consumption.

Figure 19 -- Income Elasticities of Demand for Meat
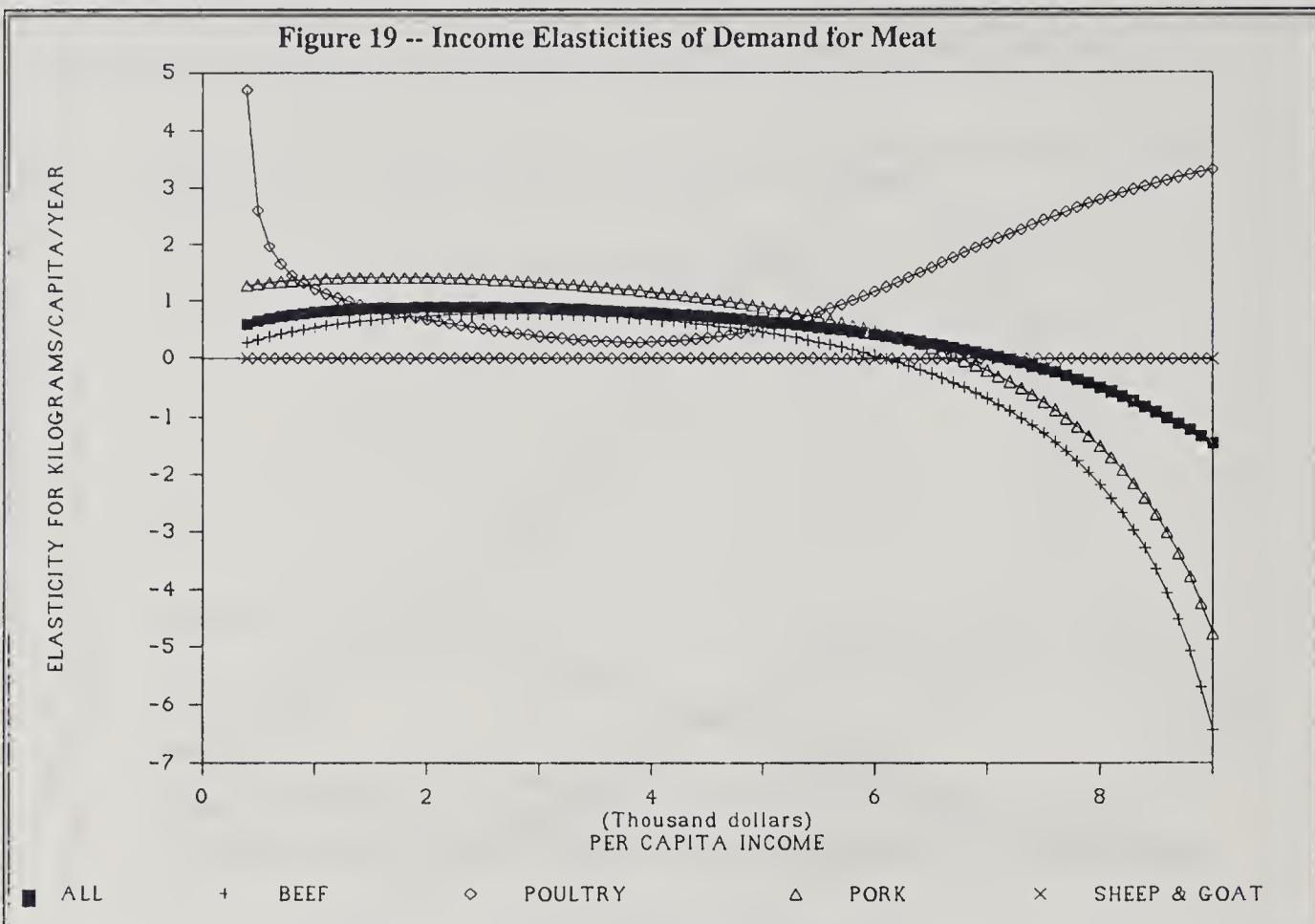
Global growth rates for the four meat groups over the 105 countries studied emphasize which categories have changed the most over time. Poultry consumption measured in kilograms per capita per year grew from a global average of 2.9 in 1961-63 to 5.8 in 1979-81, increasing at a rate of 3.9 percent compounded annually. Pork consumption grew at an annual rate of 2 percent over the same period, from 7.8 to 11.1 kilograms per capita. Beef consumption grew only 0.4 percent annually, from 10.1 to 10.9 kilograms per capita. Sheep and goat consumption declined steadily from 2.1 to 1.7 kilograms per capita over the period, falling 1.2 percent annually.

Implications for Feed Use

Growth in demand for meat has caused many nations to encourage livestock production, instead of increasing imports of livestock. Sarma and Yeung state: "Large imports of livestock products into many developing countries may not be feasible because of foreign exchange difficulties, high cost of transport, preference for fresh meat, or other reasons" (18). Increased livestock production generally requires the use of feedgrains.

As seen in figure 13, meat demand measured as a percentage of diet increases over stages I through V, rising rapidly in stages II, III, and IV (from about $1,300-$6,200). However, feed utilization occurs only in those countries that can afford to use grain as feed rather than as food. These countries are not the lowest income developing nations. Regier and Goolsby aptly described why this is so:

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"At the lowest level of income, most commodities capable of being used as food are consumed by man, if they can be obtained. Nearly all grain is used as food. Livestock must scavenge or graze. They cannot be fed with commodities eligible for use as human food, since this is too costly. Nor can these scrawny, ill-nourished animals be casually slaughtered for food, since they represent too much wealth alive. With advancing affluence from this extremely low level, increasing amounts of grain can be spared for livestock. Feed grain appears as a socially identifiable commodity. The demand for meat comes to vie with the demand for bread in determining grain allocation. Poor societies can divert little feed grain from the food production process. Rich societies reserve a small portion for food and allocate the bulk of their grain supplies to livestock" (17).

For countries that can afford to feed animals grains usually consumed by humans, large-scale production techniques are often employed. The large-scale production of certain types of livestock requires confining the animals, rather than allowing them to forage for food. According to Sarma and Yeung, "The analysis of past trends in meat consumption has shown that the rapidly rising demand for livestock products in developing countries has been met by increased production of pigmeat and poultry meat. This is understandable because the production cycles for pigs and poultry are short, and quick results can be obtained" (18). Also, pigs and poultry are much more efficient converters of plant calories into meat calories than are cattle. Demand for pork and poultry meat shows the largest increases as economic development occurs, as was seen in the preceding section. Large-scale poultry and pork production are primarily confinement operations and, thus, highly dependent on the use of feedgrains.

This line of reasoning suggests that the derived demand for feedgrains will grow along with the increased demand and production of meat resulting from increased incomes. The analysis of Regier and Goolsby found that

"when the feed grain share (of total domestic utilization across countries) is regressed directly on per capita meat consumption, per capita grain consumption for food, and the grain-meat ratio, ... the feed grain share rises directly with meat consumption and the grain-meat ratio and inversely with grain consumption for food" (17). From results of further analysis, they add: ". . . the intensity of grain feeding of livestock is related in a positive way to both per capita income and level of development. Such grain feeding is significantly related, but in a negative way, to the proportion of bovine meat in total meat output. The intensity varies positively with the proportion of poultry meat in total meat production" (17).

The increasing meat demand for pork and poultry, both of which require extensive feedgrain use, indicates that the derived demand for feedgrains occurs most in those countries undertaking large-scale pork and poultry production enterprises.

Potential for Trade

John Mellor describes various stages of economic growth, which relate food demand to production and imply trade potential:

"At an early stage of economic growth, people are very poor, desperately wishing to consume more food, yet unable to do so because of low incomes. In this stage, poverty causes high death rates and hence only modest rates of population growth, while per capita income grows hardly at all. The result is a 3 percent or less growth rate in effective demand for food. That rate that can be met by more human effort on a slightly expanded land base. In this stage, population growth roughly meets its own demand for food. . . . As development occurs, the population growth rate increases. But, even more importantly, income begins to grow rapidly, and the two together increase the growth rate of demand for food by some 30 percent over the earlier phase. Such a rate of growth in food demand exceeds all but the most rapid known rates of food production growth. In practice, high income growth reduces two of the previous stages' sources of growth -- expansion onto poorer, less-productive land area and the use of labor to intensify production at lower and lower returns to that labor. Thus prolonged and continued technological innovation in agriculture is needed in this stage, both to balance loss in

production sources and to meet rapid growth in demand. Even 2 to 3 percent growth rates in land productivity are considered high. It is for this reason that most countries in the high growth, medium-income stage find it necessary to rely upon increasingly rapid growth in food imports to meet much of demand growth. It is only countries with unusual potential to expand onto high productivity land areas that can avoid this phenomenon. . . . In later stages, of course, population growth rates decline and growth in income begins to have little effect on demand for food. Meeting demand growth then becomes more manageable, particularly since by then food production growth rates have become institutionalized at high levels. It is in this stage that food imports become unnecessary and agricultural surpluses begin to accrue" (9).

To summarize, Mellor states that as income increases for medium-income stage countries, food demand will increase more rapidly than the capacity to increase food production, except for those countries with an ample supply of highly productive land. Hence, most countries are forced to rely on imports to satisfy the increasing food demand.

According to Robert Paarlberg, trade potential is not limited to those forced to import food commodities, but "even for agriculturally successful developing countries, some of the agricultural inputs needed to satisfy these enriched dietary demands will be cheaper to purchase from abroad than to produce at home" (12). He further indicates that the import growth will come from the high-income developing countries, rather than the low-income developing countries, because of their much greater purchasing power. The International Food Policy Research Institute (IFPRI) agrees that trade potential will be driven by demand in the middle- and upper-income developing countries, especially by the derived demand for feed (7).

Paarlberg continues: "U.S. agriculture, which is the world's most efficient producer and largest exporter of high quality foodgrains and animal feedstuffs, is obviously well positioned to prosper from such larger import demands" (12).

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APPENDIX A - List of Countries

Group One: List of 80 Countries Used for Wheat and Rice Equation

Argentina	Greece	Peru
Australia	Guatemala	Poland
Austria	Haiti	Portugal
Belgium - Luxembourg	Honduras	Romania
Benin	Hong Kong	Rwanda
Bolivia	Hungary	Senegal
Brazil	Iceland	Singapore
Burkina Faso	Ireland	Somalia
Burma	Israel	South Africa
Cameroon	Italy	Spain
Canada	Ivory Coast	Sudan
Chad	Jamaica	Sweden
Chile	Kenya	Switzerland
Colombia	Malawi	Tanzania
Costa Rica	Mali	Togo
Czechoslovakia	Mauritania	Trinidad & Tobago
Denmark	Mexico	Uganda
Dominican Republic	Mozambique	United Kingdom
Ecuador	Netherlands	United States
El Salvador	New Zealand	Uruguay
Ethiopia	Nicaragua	USSR
Finland	Niger	Venezuela
France	Nigeria	Yugoslavia
Gabon	Norway	Zaire
German Democratic Rep.	Panama	Zambia
Germany, Fed. Rep. of	Papua New Guinea	Zimbabwe
Ghana	Paraguay	

Group Two: List of 25 Countries Not Used in Wheat and Rice Equation

Algeria	Malaysia
Bangladesh	Mauritius
China (excluding Taiwan)	Morocco
Egypt	Pakistan
Guyana	Philippines
India	Republic of Korea
Indonesia	Sierra Leone
Iran	Sri Lanka
Iraq	Syria
Japan	Thailand
Jordan	Tunisia
Liberia	Turkey
Madagascar	

APPENDIX B - Percent RDA Estimations

The following equations fit the best for the share of each commodity in the diet as a function of percent RDA.

Coarse Grains as a Percentage of Diet

$$\ln\left(q_{cg}\right) = \ln(\alpha) - \beta * \ln(RDA)$$

$$\ln\left(q_{cg}\right) = 33.03 - 6.85 * \ln(RDA)$$

where q_{cg} = percentage of coarse grains in the diet

RDA = percentage Recommended Daily Allowance

	α	$\ln(RDA)$
t calculated	24.09	-23.07
t critical	1.645	-1.645

R^2 = .2681 Adjusted R^2 = .2676

F calculated:	1453.00
F critical:	3.84

Wheat and Rice as a Percentage of Diet

$$\ln\left(q_{wr}\right) = \ln(\alpha) - \beta * \ln(RDA) + \gamma * (\ln(RDA))^2 - \delta * (\ln(RDA))^3$$

$$\ln\left(q_{wr}\right) = 83.17 - 3.10 * \ln(RDA) + 0.04 * (\ln(RDA))^2 - 0.00013 * (\ln(RDA))^3$$

where q_{wr} = percentage of wheat and rice in the diet

	α	$\ln(RDA)$	$(\ln(RDA))^2$	$(\ln(RDA))^3$
t calculated	1.84	-2.31	2.88	-3.16
t critical	1.645	-1.645	1.645	-1.645

R^2 = .3281 Adjusted R^2 = .3264

F calculated:	1181.00
F critical:	2.6

Meat as a Percentage of Diet

$$q_m = \alpha - \beta * RDA + \gamma * RDA^2 - \delta * RDA^3$$

$$q_m = 172.06 - 5.07 * RDA + 0.05 * RDA^2 - 0.00014 * RDA^3$$

where q_m = percentage of meat in the diet

	α	RDA	RDA^2	RDA^3
t calculated	8.88	-8.73	8.48	-7.78
t critical	1.645	-1.645	1.645	-1.645

R^2 = .4854 Adjusted R^2 = .4844

F calculated:	523.67
F critical:	2.6

APPENDIX C - Findings on the Meat Subgroups

Graphs of the data for the meat subgroups (beef and buffalo; poultry; pork; and sheep and goat) suggested that separate demand functions existed. As a major coarse grain exporter, the United States is particularly interested in the derived demand for feedgrains. Since feedgrain demand is believed to vary according to the type of meat consumed, equations were estimated for the four meat subgroups using both measures of consumption. The best fitting equational forms and corresponding results follow.

Meat Subgroups as a Percentage of Diet

Beef and Buffalo Meat as a Percentage of Diet

$$q_{bl} = \alpha + \beta * x - \gamma * x^2 - \delta * x^3$$

$$q_{bl} = 0.9678 + 0.0008 * x - 0.208 E - 7 * x^2 - 4.5 E - 12 * x^3$$

where q_{bl} = percentage of beef and buffalo meat in the diet

	α	x	x^2	x^3
t calculated	8.22	4.29	-0.30	-0.63
t critical	1.645	1.645	-1.645	-1.645

R^2 = .3150 Adjusted R^2 = .3136

F calculated: 488.67
F critical: 2.6

Poultry Meat as a Percentage of Diet

$$q_{pl} = -\alpha + \beta * x - \gamma * x^2 + \delta * x^3$$

$$q_{pl} = -0.2839 + 0.0010 * x - 0.2684 E - 6 * x^2 + 2.2 E - 11 * x^3$$

where q_{pl} = percentage of poultry meat in the diet

	α	x	x^2	x^3
t calculated	-6.99	17.96	-13.35	11.66
t critical	-1.645	1.645	-1.645	1.645

R^2 = .4000 Adjusted R^2 = .3988

F calculated: 518.67
F critical: 2.6

Pork Meat as a Percentage of Diet

$$q_{pk} = \alpha + \beta * x + \gamma * x^2 - \delta * x^3$$

$$q_{pk} = 0.3099 + 0.0004 * x + 0.3381 E - 6 * x^2 - 2.7 E - 11 * x^3$$

where q_{pk} = percentage of pork meat in the diet

	α	x	x^2	x^3
t calculated	1.66	1.58	3.71	-3.12
t critical	1.645	1.645	1.645	-1.645

$R^2 = .6419$ Adjusted $R^2 = .6412$

F calculated: 26.67
F critical: 2.6

Sheep and Goat Meat as a Percentage of Diet

$$q_{sg} = \alpha - \beta * x$$

$$q_{sg} = 0.6758 - 0.00003 * x$$

where q_{sg} = percentage of sheep and goat meat in the diet

	α	x
t calculated	21.52	-3.10
t critical	1.645	-1.645

$R^2 = .0063$ Adjusted $R^2 = .0056$

F calculated: 191.82
F critical: 3.84

Meat Subgroups as Quantities Consumed

Beef and Buffalo Meat

$$q_{bf} = \alpha + \beta * x + \gamma * x^2 - \delta * x^3$$

$$q_{bf} = 3.9395 + 0.0032 * x + 0.5576E - 6 * x^2 - 0.9E - 10 * x^3$$

where q_{bf} = beef and buffalo kilograms per capita per year

	α	x	x^2	x^3
t calculated	9.29	4.74	2.19	-3.39
t critical	1.645	1.645	1.645	-1.645

$R^2 = .4963$ Adjusted $R^2 = .4956$

F calculated: 698.67
F critical: 2.6

Poultry Meat

$$q_{pl} = -\alpha + \beta * x - \gamma * x^2 + \delta * x^3$$

$$q_{pl} = -1.8770 + 0.0064 * x - 0.1445E - 5 * x^2 + 1.2E - 10 * x^3$$

where q_{pl} = poultry kilograms per capita per year

	α	x	x^2	x^3
t calculated	-7.86	18.13	-11.73	10.37
t critical	-1.645	1.645	-1.645	1.645

R^2 = .4871 Adjusted R^2 = .4864

F calculated: 740.67
F critical: 2.6

Pork Meat

$$q_{pk} = -\alpha + \beta * x + \gamma * x^2 - \delta * x^3$$

$$q_{pk} = -0.0353 + 0.0019 * x + 0.1578E-5 * x^2 - 1.7E-10 * x^3$$

where q_{pk} = pork kilograms per capita per year

	α	x	x^2	x^3
t calculated	-0.06	2.36	5.65	-6.17
t critical	-1.645	1.645	1.645	-1.645

R^2 = .6135 Adjusted R^2 = .6129

F calculated: 705.67
F critical: 2.6

Sheep and Goat Meat

$$q_{sg} = \alpha - \beta * x$$

$$q_{sg} = 3.0618 - 0.00006 * x$$

where q_{sg} = sheep and goat kilograms per capita per year

	α	x
t calculated	24.82	-1.39
t critical	1.645	-1.645

R^2 = .0009 Adjusted R^2 = .0004

F calculated: 2182.00
F critical: 3.84